• Volume 8D, Number 2, February 1960

מוסד ויצמן למדעים במדעי הטבע ובטכנולוגיה בישראל • ירושלים

The Weizmann Science Press of Israel • Jerusalem

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Bull. Res. Counc. of Israel. D. Bot.

Continuing the activities of the
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OF ISRAEL

MIRIAM BALABAN
Editor

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THE SPECIES OF *CAPPARIS* IN THE MEDITERRANEAN AND THE NEAR EASTERN COUNTRIES

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ABSTRACT

The species and varieties of *Capparis* occurring in the Mediterranean and Near Eastern countries, and particularly those growing in Israel, are reviewed here. An attempt is made to clarify their taxonomy and nomenclature as well as their phylogenetical relations.

INTRODUCTION

The large tropical and subtropical genus *Capparis* is represented in the Mediterranean and in the Near Eastern countries by a few species and a number of varieties, which have been partly misidentified in the herbaria and in the Floras concerned. With the aim to clarify the taxonomy of these species I have examined the specimens concerned in the herbaria of the British Museum, London (BM), Royal Botanic Gardens, Kew (K), the Royal Botanic Garden, Edinburgh (E), Laboratoire de Phanérogamie du Muséum National d'Histoire Naturelle, Paris (P), the Hebrew University, Jerusalem (HUJ), as also living specimens of this group occurring in Palestine and elsewhere in the East Mediterranean countries. As the species delimitation in this highly variable group is exceedingly difficult, no wonder that there is a divergence of opinions as to the rank accredited to the various taxa and to their subordination. Examination has shown that specific value should be attributed only to more or less obvious structural characteristics of the flower associated with some constant vegetative features. Thus the group of taxa known as *C. spinosa*, *C. rupestris* and *C. aegyptia*, marked by their slightly zygomorphous flowers and round or round-ovate leaves has been included together with a number of other taxa within one species, while *C. sicula*, *C. ovata*, *C. herbacea* and others with their stronger zygomorphy of petals and sepals, the specific structure of their nectariferous pit, their oblong to elliptical leaves, have been classed under another species. Although the limits of such species are not always clear-cut, as there are marked transitions from one species to another due to intercrossing in their meeting areas, the above morphological characters were nevertheless helpful to disentangle this "chaotic" group without experimental approach. The following species and varieties have been accepted in the present revision.

Received November 22, 1959.

1. *C. spinosa* L.
   var. *spinosa*
   var. *inermis* Turra
   var. *parviflora* J. Gay
   var. *aegyptia* (Lam.) Boiss.
   var. *aravensis* Zoh.
   var. *pubescens* Zoh.
   var. *deserti* Zoh.
2. *C. ovata* Desf.
   var. *ovata*
   var. *sicula* (Duham.) Zoh.
   var. *herbacea* (Willd.) Zoh.
   var. *palaestina* Zoh.
   var. *microphylla* (Ledeb.) Zoh.
   var. *kurdica* Zoh.
3. *C. leucophylla* DC.
   var. *leucophylla*
   var. *parviflora* (Boiss.) Zoh.
4. *C. mucronifolia* Boiss.
5. *C. cartilaginea* Decne.
6. *C. decidua* (Forsk.) Edgew.

The above taxa are also phytogeographically or ecologically rather well characterized, though certain varieties intercross in their overlapping areas. In fact, intermediates have been found not only between some varieties of *C. spinosa*, but also between var. *aegyptia* and var. *sicula*, and between the latter and var. *herbacea*. There are also some indications of intercrosses between *C. ovata* var. *palaestina* and *C. leucophylla* (in Turkey). It seems to us that the three first-mentioned species of the above list are relatively young and perhaps in statu nascendi, although my observation on living specimens of some varieties both of the *spinosa* and *ovata* groups reveals high constancy of characters.

ENUMERATION OF SPECIES

1. a) **Capparis spinosa** L. var. **spinosa**

C. spinosa L. Sp.Pl.1: 503 (1753); Willd. Sp.Pl.2: 1130 (1799); Duham. Nouv. 1: 137 (1801); Bertol. Fl. ital. 5: 301 (1842). — *C. spinosa* L. α *genuina* Boiss. Fl.or. 1: 420 (1867). — *Icon*: Lam. Ill.2: t.446 (1793); Duham. Nouv. 1: t.34 (1801); Bercht. et Presl, Rostl.2: t.40 (1825); Reichb. Icon.Fl.germ.3: t.4487 (1838–39).

This variety has large, round-ovate, glabrous leaves and the largest flowers within the whole group of species concerned here. The stem and branches are relatively thick, the stipular spines vary in length, sometimes being short and weak. In the West-Mediterranean countries it has been and still is under cultivation and its indigeneity there is dubious. It seems to us that this plant has escaped from cultivation and its present habitats, at least in W. Europe, are secondary.

Linné's specimen in the Hortus Siccus Cliffortianus, No. 203 under *C. aculeata* does not agree well with the phrase cited by him from Bauhin, Pin.: 480, 1623 and with what is commonly accepted as typical *C. spinosa*; it is without flowers and may belong to one of Linné's varieties.

Representative specimens. SPAIN: Regnum Granatense, prov. Malacitana ad rupes, prope stationem viae ferreae ad Alora, 12.6.1874 *Huter, Perta* et *Rigo*, ex itinere hispanico 237 (E). W. BALKAN: Insula Assos in rupibus, 1883 *P. Sintenis* Iter trojanum, s.n. (E).

Distribution: I have seen specimens from Spain, Minorca, France, Italy, Yugoslavia, Greece, Cyprus, Algeria, Egypt, Turkey, Iraq. It is recorded by Duhamel (l.c.) also from Palestine. Indeed the few specimens collected in Palestine (HUJ) are intermediate between var. *spinosa* and var. *aegyptia*.

1. b) **C. spinosa** var. **intermis** Turra

Fl. ital. Prodr.: 65 (1780); Savi, Fl. Pis. 2: 2 (1798). — *C. orientalis* Duham. Nouv. 1: 142 (1801).—*C. rupestris* Sibth. et Sm. Fl. gr. Prodr. 1: 355 (1806), Fl. gr. 5: 71 (1825); Bertol. Fl. ital. 5: 302 (1842); Rech. Fl. aegaea: 205 (1943). — *C. peduncularis* Presl, Del. Prag.: 20 (1822). — *C. spinosa* L. var. *rupestris* (Sibth. et Sm.) Viv. Fl. lib. Spec.: 26 (1824); Boiss. Fl. or. 1: 421 (1867). — *Icon.*: Bot. Mag. 9: t. 291 (1795 sub *C. spinosa* L.); Sibth. et Sm. Fl. gr. 5: t. 487 (1825); Reichb. Icon. Fl. germ. 3: t. 4488 (1838–39), utraeque sub *C. rupestri;* Bercht. et Presl, Rostl. 2: t. 41 (1825, sub *C. pedunculari*).

Differs from var. *spinosa* by the pendulous habit of branches, the broad-ovate sometimes succulent leaves, round at apex, and sub-cordate at base, by the lack of stipular spines (often caducous at a young stage). It is mostly confined to cliffs facing the sea and varies slightly in size of leaves.

Representative specimens. BALEARES: Soller, 8.6.1911 *H. Bianor* 125 (E). AEGAEA: Karpathos, Vugunda, near cliff Akrotinia, dry NW cliff, 7.1950 *P. H. Davis* 18042 (E).

Distribution: I have seen specimens from Majorca, Sardinia, Sicily, Malta, Yugoslavia, Albania, Greece, Crete, Turkey, Tripolitania, Marmarica, Abyssinia, Chitral and Kashmir. Duhamel (l.c.) mentions this species from Palestine, erroneously citing Tournefort (Voy. Levant 1: 75, 1718). So far it has not been observed here.

1. c) **C. spinosa** var. **parviflora** J. Gay in herb.

In the Kew Herbarium there is a specimen collected from Barthelemy near Nice (France) and described by J. Gay as *C. parviflora*. It is distinguished from *C. spinosa* mainly by the absence of stipular spines and the small flowers about 2–3 times shorter than those of typical *C. spinosa*. The leaves are broad-ovate, cordate. Here is the original description of J. Gay: "Affinis *C. spinosae* a quae differt, praeter absentium aculeorum, ut videtur, constantam foliis ovatis non orbicularibus basi plus minus cordatis, non integris, floribus triplo minoribus, filamentisque longiore petalo duplo longioribus non eadem vix superantibus". France, dans le Jardin du Couvent à St. Barthelemy près de Nice, cultivée le 25e Septembre 1821.

1. d) **C. spinosa** var. **aegyptia** (Lam.) Boiss.

Fl. or. 1: 420 (1867). — *C. aegyptia* Lam. Encycl. 1: 605 (1785); Duham. Nouv. 1: 140 (1801); Del. Fl. Egypt.: 237 (1813). — *Icon.*: Del. Ill: t. 31 (1812). (Figure 1).

This taxon is generally well identified in the herbaria, although it is rather polymorphous as to shape and size of leaf. In the most common form the stems and branches are purplish, at least in their upper part; the whole plant is glabrous except

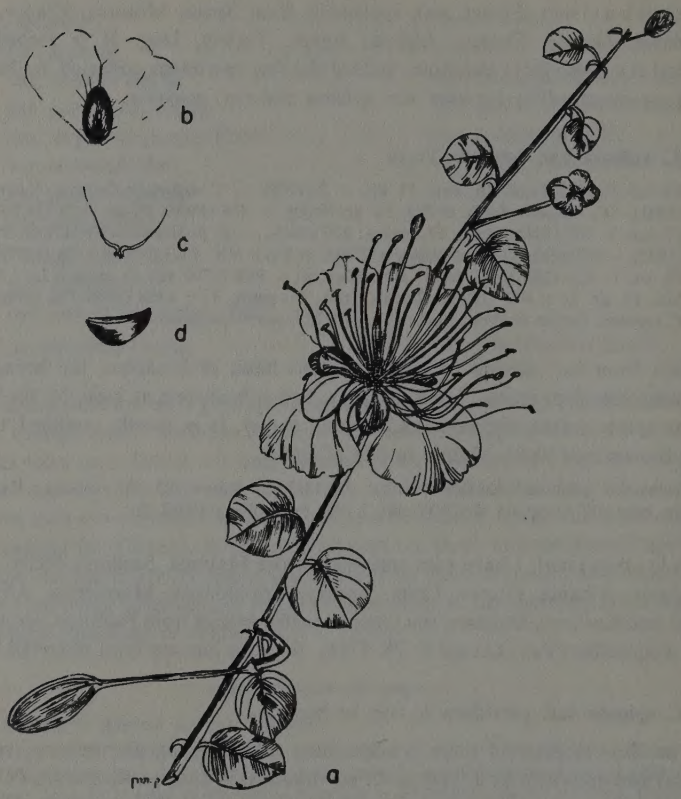

Figure 1

Capparis spinosa L. var. *aegyptia* (Lam.) Boiss. *a*, flowering branch; *b*, posterior pair of petals showing the nectariferous pit; *c*, cross-section of the above; *d*, anterior sepal.

for the youngest leaves; the leaves are about half the size of var. *spinosa*, they are orbicular, ovate-orbicular to orbicular-cuneiform, their apex is rounded or retuse with a small mucro or prickle; the anterior petals are obovate or orbicular, 2 × 1.5 cm, elongating after anthesis.

Representative specimens. EGYPT: Desert du Laire, s. d. *Aucher-Eloy* 398 (BM). PALESTINE: Upper Galilee, Tel el Kadi, 7.1954 *D. Jaffe* 96 (HUJ); Samaria, Wadi A'ra 6.1957 *M. Zohary* 91 (HUJ). Judaean Mts., Sha'ar Hagai 9.1949 *M. Zohary* 92 (HUJ). TURKEY: Asmaniye to Adana, waste ground and banks of cultivated fields, 29.5.1934 *E. K. Balls* 1199 (E). AEGAEA: Samos, 8.8.1887 *Forsyth Major* 653 (E).

Distribution: I have seen specimens from Morocco, Algeria, Tunisia, Tripolitania, Egypt, Palestine, Lebanon, Turkey, Crete, Iran and Afghanistan.

Specimens of this variety intergrading with var. *sicula* have been found in Cyprus and Morocco.

1. e) **C. spinosa**. L. var. **aravensis** Zoh. nom. nov.

Frutex perennans, 80–120 cm altus. Folia succulenta, valde glauca. Fructus oblongus, 3–4 cm longus. Ceterum ut in var. *aegyptia*.

Evergreen shrub; leaves succulent, orbicular or broad-ovate, rounded, truncate or emarginate, rarely leaves obcordate, 2–3 cm in diam., surface covered with a thick, blue-green, waxy bloom. Flowers of the same size as in var. *aegyptia*. Fruit oblong, 3–4 cm long.

Representative specimens. PALESTINE: Judaean Desert, Ein Far'a, dry shady rocks, 26.12.1946 *P. H. Davis* 5048 (E); env. of Dead Sea, n. Ein Gedi, Wadi Areija, 5.1951 *J. De Angelis* 104 (HUJ); Arava Valley, Wadi Fuqra, 20.4.1954 *M. Zohary* 20757 (HUJ type!).

Distribution: I have also seen specimens from the Sinai Peninsula.

This variety agrees with Shaw's (Catal. Pl. Afr. et Asiae, African specimen No. 112, 1738) description of a specimen referred to by him as *C. arabica:* "Folia habet glauca, crassa, succulenta, rotunda, uncialia. Fructus quem vidi pollicis fuit". The specimen which Shaw described was approximately 1.50 m high.

Duhamel, Nouv. 1: 144 (1801) erroneously relates Shaw's specimen to his *C. sinaica*. The latter which has an arborescent habit and a fruit of an egg's size, and which is based on a description by Belon (Observ. singul. Liv. II, Chap. 60, 1553) is no doubt identical with *C. cartilaginea* Decne. (see p. 11). Var. *aravensis* has not been recorded from the region after Shaw, and it is very poorly represented in herbaria. It is limited in its distribution to hot valleys of Sinai and Southern Palestine. Unlike var. *aegyptia*, which is a hemicryptophyte, it is a chamaephyte readily recognised by its grey-bluish leaves generally larger and thicker than in the latter. In Wadi Fuqra both varieties occur and transitional forms between them, probably due to intercrossing, have been found.

1. f) **C. spinosa** var. **pubescens** Zoh. var. nov.

Folia vel rami vel utrique pubis vel pilis iterdum caducis sparsim vel dense obsiti, cetera ut in var. *aegyptia*.

Leaves or branches or both sparsely to densely hairy, otherwise as in var. *aegyptia*.

Representative specimens. EGYPT: Galala, rocks, 4100 ft, 1944 *P. H. Davis* 8062 (K, type!). ARABIA: entre Sheikh Othman et Lahady, s. d. *A. Deflers*, Iter arabicum 104 (P). PERSIA: Prov. Kerman, Montes Djamal Bariz, inter Bam and Djiroft in declivibus borealibus, inter Deh Bakri et Darzin 1200 m, 1948 *K. H.* et *F. Rechinger* 3708 (E).

Distribution: Egypt, Saudi Arabia, Iran. In the latter I have seen a specimen approaching *C. leucophylla* in the indumentum of the leaves.

1. g) **C. spinosa** L. var. **deserti** Zoh. var. nov.

Folia plura, ca 10 mm vel minus longa, glabra vel pubescentia. Flores illis var. *aegyptia*. dimidio minores.

Leaves and flowers about half the size of these in var. *aegyptia*. This is a "weak" variety because small-leaved forms occur almost in all groups.

Representative specimens. EGYPT: Wadi Nosz, entrance to Wadi Lehiani (Bir Derheba), 27.3.1944 *P. H. Davis* and *N. Feinbrun* 5076–7 (HUJ, type!). AFGHANISTAN: Afghanistan Delimitation Commission, 1884–1885 *J. E. T. Aitchison* 590 (BM).

Distribution: I have also seen specimens from Pakistan (Sind).

Additional forms of *C. spinosa* may well be found through further investigations. Despite the multitude of forms and the occurrence of some transitions between them, as well as between the latter and some forms of *C. sicula* and *C. leucophylla* in the meeting areas, the individual varieties are generally readily distinguishable, and seem to be genetically fixed; they also show phytogeographical and ecological peculiarities.

2. a) **C. ovata** Desf. var. **ovata**

C. ovata Desf. Fl. alt. 1: 404 (1798); Willd. Sp. Pl. 2: 1131 (1799); Duham. Nouv. 1: 139 (1801); Guss. Sup. 2: 171 (1832–43); Bertol. Fl. ital. 5: 305 (1842). — *C. fontanesii* DC. Prodr. 1: 245 (1824) non Presl, Fl. sic. 1: 111 (1826). — *C. spinosa* L. var. *ovata* (Desf.) Batt. ex Jah. et Maire: 314 (1932) non *C. spinosa* L. var. *β ovata* Sibth. et Sm. Fl. gr. Prodr. 1: 355 (1806), nec *C. ovata* M. B. Fl. taur.-cauc. 2: 1 (1808), 3: 361 (1819), neque *C. ovata* Guss. Pl. rar.: 210 (1826) et Fl. sic. Prodr. 2: 4 (1828). — *Icon.:* Lobel. Icon.: t. 634 (1581); Tabernemont. Icon.: 444 (1588–91).

Representative specimens. MOROCCO: Tinghir, dry rocky slopes, 1.5.1936 *C. S. Garnett* 9223/8 (BM); El Zaid, Montes de Quebdana, 5.7.1930 *Sennen* et *Mauricio* 7509 (BM; somewhat intermediate between var. *ovata* and var. *sicula*).

Distribution: I have also seen specimens from Grand Atlas and Algeria.

This is mainly a North-West African taxon but one which has been most confused in the herbaria and in nomenclature. It has often been synonymized with *C. sicula* because some extreme forms of this variety seem to intergrade on one hand with var. *sicula* and on the other with var. *spinosa*. I have seen a specimen of *C. ovata* in Desfontaines's herbarium (National Muséum, Paris) with ovate-oblong leaves which rather approaches Linné's specimen in the Hortus Siccus Cliffortianus. But it seems to me that this is not identical with Desfontaines's original plant as it does not resemble the illustration of Boccone (Ic. Descr. t. 42, f. 3, 1674) cited by. Desfontaines. Indeed, Boccone's illustration resembles closely *C. ovata* as understood by Gussone (Sup. 2: 171, 1832–43) who has seen Desfontaines's authentic

specimen and who describes the leaves as follows: "folia exacte ovata basi subcordata, obtusiuscula cum acumine, stipulae setaceae ac rectae". Typical var. *ovata* has ovate, hairy or glabrous leaves, acute or acuminate at apex and broad truncate or rounded or slightly cordate at base. The stipular spines are generally short or setaceous or lack altogether. Flowers are of the size of var. *aegyptia* or somewhat larger. The fruit is pear-shaped. Bertoloni (l.c.) distinguishes this variety as follows: "...differt a *Cappariде sicula* foliis subcordato-ovatis, pollicem, et sesquipollicem longis, longiusque petiolatis, aculeis stipularibus setaceis, rectis. *Capparis egyptiaca*... habet folia exigua, subrotunda, apice integra, vel emarginata, semper in medio acutata mucrone insigni, recto, aculeos stipulares validiores, pedunculos breves, folio subaequales, flores minores, petala obovata, baccam oblongam, utrinque angustatam". It seems that in Sicily var. *ovata* meets var. *sicula* and intercrosses with it but also in North-West Africa var. *ovata* may intercross with var. *sicula* and var. *aegyptia*.

2. b) **C. ovata** Desf. var. **sicula** (Duham.) Zoh. comb. nov.

C. sicula Duham. Nouv. 1: 159 (1801); Guss. Sup. 2: 171 (1832–43); Bertol. Fl. ital. 5: 304 (1842); Rech. Fl. aegaea: 206 (1943). — *C. fontanesii* Presl, Fl. sic. 1: 111 (1826), non DC. Prodr. 1: 245 (1824). — *C. ovata* Guss. Pl. rar.: 210 (1826; excl. synonymis nonnullis).— *C. spinosa* L. var. β vel γ L. Sp. Pl. 1: 503 (1753); var. β Sibth. et Sm. Fl. gr. Prodr. 1: 355 (1806). — *C. spinosa* L. var. *sicula* (Duham.) Hausskn. in Mitt. thür. bot. Ver., N. F. 5:41 (1893). — *C. spinosa* L. var. *canescens* Coss. Not. Pl. crit. 1: 28 (1848); Boiss. Fl. or. 1: 420 (1867). — *Icon.*: Sibth. et Sm. Fl. gr. 5: t. 486 (1825, sub *C. spinosa*); Bercht. et Presl, Rostl. 2: t. 40 (1825, sub *C. ovata*).

Representative specimens. MOROCCO: Grand Atlas, Azilal, rochers calcaires à Ifrana 1900 m, 31.5.1927 *E. Jahandiez* 311 (E). GREECE: Macedonia near Salonika, 25.8.1917 *M. Wilson* 121 (E).

Distribution: I have seen specimens from Spain, Italy, Sicily, Yugoslavia, Greece, the Aegaean Archipelago, Cyprus, Turkey, Morocco, Algeria, Tunisia, Tripolitania.

While *C. ovata* Desf. var. *ovata* is a rare variety, occurring mainly in North-West Africa, var. *sicula* is most common in all Mediterranean countries. These two varieties have been frequently confused especially after the publication of *C. ovata* M. B. later changed by Willd. (l.c.) to *C. herbacea*.

Var. *sicula* is rather polymorphous and includes also some extreme forms pointing to var. *ovata* (see below) in NW Africa and to var. *aegyptia* in Crete and Cyprus. Nevertheless it possesses a series of characteristics of its own, such as oblong to elliptical leaves, pubescence of the stems and buds, markedly zygomorphous flower bordered nectariferous pit, etc.

Mention should be made of a particular form with elliptical leaves attenuate at base and apex, mainly common in Cyprus.

2. c) C. **ovata** Desf. var. **herbacea** (Willd). Zoh. comb. nov.

C. herbacea Willd. Enum. Hort berol.: 560 (1809); Guss. Pl. rar.: 210 (1826). — *C. ovata* M. B. Fl. taur.-cauc. 2: 1 (1808), 3: 361 (1819), non Desf. Fl. atl. 1: 404 (1798); Ledeb. Fl. ross. 1: 234 (1842); Busch, Fl. cauc. crit. 3: 719 (1910) p. p. — *Icon.*: M. B. Cent. Pl. rar. 2, 2: t. 68 (1843).

Representative specimens. CRIMEA: Abhänge d. Sokoll bei Sudak, 3.7.1896 *A. Callier* 29 Iter tauricum secundum 123 (E). TURKEY: Prov. Hakkari, Zab. gorge near Kalolans, eroded slopes, 3.8.1954 *P. H. Davis* and *O. Polunin* 23, 870 (E). PERSIA: Aderbejdzan, prope Kerim-abat, 17.6.1916 *A. B. Schelkownikow* Herb. Mus. Georgici 150 (E).

Distribution: I have seen specimens from Crimea, Turkey, Caucasus, Armenia, Transcaucasia, Azerbajdzhan.

The original description by Marschall von Bieberstein of *C. herbacea* is very poor. It was widened by Bush (l.c.). But Busch, apparently, did not conceive this species correctly, since he refers it to the illustration of Sibthorp and Smith which definitely represents var. *sicula*. It is also astonishing that in Flora U.R.S.S. (vol. 8:2, 1939) this taxon has been included within *C. spinosa*, although it has a series of obvious characteristics sufficient for keeping it apart from *C. spinosa*. These are the strongly zygomorphic corolla, the strongly nerved leaves with a short, acuminate apex, the erect or horizontal stipular spines, the long anterior petals, etc. The material of this species in various herbaria is rather scant.

2. d) C. **ovata** Desf. var. **palaestina** Zoh. var. nov. (Figures 2 and 3).

Frutex griseo-cano-viridis, 70–100 cm altus et latus, ramis erectis vel divaricatis, albo-canescentibus. Folia elliptica, oblonga, raro ovata vel obovata, apice acuto, mucronato, griseo-canescentia, 15–25 mm longa, 10–20 mm lata, stipulis spinosis, uncinatis. Alabastra griseo- canescens, unilateraliter gibbosa. Flores longe pedunculati; sepalum posterius multo latius et longius quam altera; corolla alba; petala anteriora oblonga, 15–25 mm longa, valde divergentia, alis papilionis similia, posteriora parte inferiore margine valde incrassato et elevatim plicato, cavum nectariferum profundum formantia; stamina plura, anteriora petalis longiora, posteriora eis breviora, filamentis albis, antheris roseis; gynophorum longum, basi pilosum. Bacca pyriformis, 30 mm longa.

Representative specimens. EGYPT: Dakhla Oasis, edge of the desert, March 1950? Herb. *R. Meinertzhagen* s.n. (BM). SINAI: Wadi el Arish, banks of Wadi, 5.1925 *A. Eig* and *M. Zohary* 119 (HUJ). PALESTINE: Upper Galilee, Wadi Hindaj 25.6.1954, *M. Zohary* 110 (HUJ, type!); Negev, Wadi Fuqra 10.5.1957 *M. Zohary* 112 (HUJ). MESOPOTAMIA: Banks of Tigris above Amara, 30.9.1918 *W. E. Evans* M/100 (E).

Distribution: I have seen specimens from Cyrenaica, Egypt, Sinai, Palestine, Syria, Turkey as well as from Iraq and Persia. It is probably an East Mediterranean vicariad of the mainly West Mediterranean var. *sicula* to which it is very closely

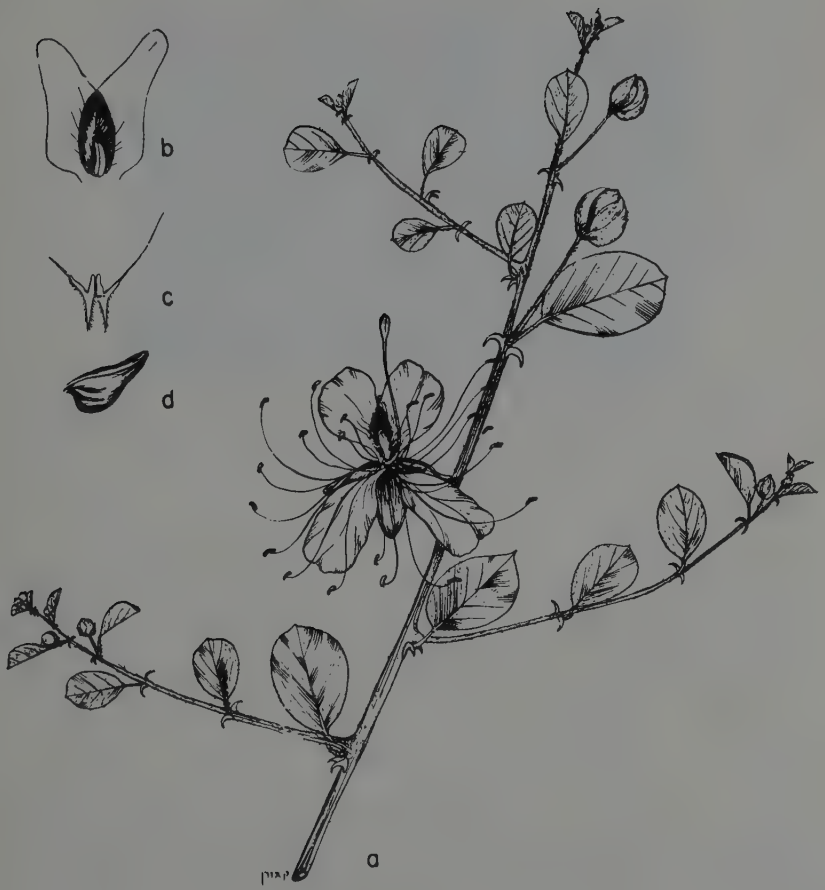

Figure 2

Capparis ovata Desf. var. *palaestina* Zoh. (Symbols as in Figure 1).

related. It differs, however, from the latter by its larger anterior sepals, its longer strongly divergent anterior petals, its soft, villous indumentum, its white filaments, etc.

In Palestine and Syria its distribution is almost exclusively semi-desertic, while var. *aegyptia* is confined to rather Mediterranean habitats. The main differential characteristics between this variety, var. *sicula*, var. *herbacea* and var. *ovata* are given in Table I.

Figure 3

Capparis ovata Desf. var. *palaestina* Zoh. Flowering branch.

TABLE I

Differential characteristics between var. ovata, *var.* palaestina, *var.* herbacea *and var.* sicula

	var. *ovata*	var. *palaestina*	var. *herbacea*	var. *sicula*
Leaf colour	bright green	grey-green	green	bright yellowish-green
Stipular spines	weak, straight, setaceous	strong, curved	straight, horizontal or upright	strong, curved
Stem	whitish	white	green	green or purplish
Indumentum of adult plants	glabrous or pubescent	all parts canescent	only stem and petioles slightly pubescent	rarely leaves slightly pubescent
Gynophore	hairy at base	hairy at base	glabrous	glabrous
Anterior petals	ovate, slightly divergent, not considerably longer than posterior	oblong, strongly divergent, 1.5–2 times longer than posterior	slightly divergent or contiguous, crisp, undulate, much longer than posterior	obovate or round, not divergent, not much longer than posterior
Filaments	purple	white	purple	purple
Nectariferous pit	?	bordered by strongly elevated folds of petals	?	bordered by elevated folds of petals

1. c) **C. ovata** Desf. var. **microphylla** (Ledeb.) Zoh. comb. nov.

C. herbacea Willd. *β microphylla* Ledeb. Fl. ross. 1: 235 (1842).

Representative specimens. SINAI: Wadi El Arish, 2.5.1925 *A. Eig* and *M. Zohary* 242 (HUJ). SYRIA: Syrian Desert, W. of Ramadi, plain, 150 m, 2.4.1933 *A. Eig* and *M. Zohary* 244 (HUJ).

Distribution: Sinai, Syria, Iraq, and Sind. Also reported by Ledebour from the eastern shore of the Caspian Sea.

Var. *microphylla* is very close to var. *palaestina*, but differs from it by the prostrate habit of its branches; leaves 8–15 mm long; flowers 10–15 mm long. This variety is fairly common in the Syrian Desert and probably in other East Mediterranean deserts, and may intergrade with var. palestina but is by no means close to var. *herbacea*.

2. f) **C. ovata** Desf. var. **kurdica** Zoh. var. nov.

Planta pumila, elegans. Folia parva, 10–15 mm longa, glabra vel glabrescentia, conspicue petiolata. Ovarium ovatum; gynophorum pedicello fructifero crassius.

Plant small, glabrous or glabrescent, small-leaved and small-flowered, leaves ovate to elliptical, 10–15 mm long, conspicuously petiolate, 2–3 times smaller than in var. *sicula*. Ovary ovate, gynophore thicker than fruiting pedicel.

Representative specimens. IRAQ: Rupes Mt. Singarae, Mai 1867 *C. Haussknecht* s.n. (K, type!); IRAN: Avroman and Shachu, in montibus calcareis, 18.7.1867 *C. Haussknecht*, s.n. (K).

Distribution: Iran, Iraq.

This mesophytic almost glabrous small-leaved and small-flowered form is close to var. *palaestina* or var. *sicula*.

3. a) **C. leucophylla** DC. var. **leucophylla**

C. leucophylla DC. Prodr. 1: 246 (1824). — *C. spinosa* L. var. *leucophylla* Boiss. Fl. or. 1: 420 (1867). — *Icon.*: Deless. Icon. 3: t. 10 (1837).

This variety is readily recognizable by its round leaves (sometimes broader than long), very short petioles, the small almost actinomorphic flowers and by its small fruits (up to 2 cm long). The petals are almost as long as the sepals. The base of the gynophore is densely beset with long hairs. In typical specimens, the whole plant is beset with a white-greyish filt. To the very short description by De Candolle some details were added by Delessert, whose illustration is very instructive.

Representative specimens. IRAQ: Mossul, s. d. *Aucher-Eloy* 403 (BM).

Distribution: I have seen specimens from Iraq and Iran.

3. b) **C. leucophylla** DC. var. **parviflora** (Boiss.) Zoh. comb. nov.

C. parviflora Boiss. Diagn. 1, 18: 4 (1842) p.p. — *C. spinosa* L. var. *parviflora* Boiss. Fl. or. 1: 420 (1867) p.p. — *C. leucophylla* DC. var. *persica* Zoh. in Herb.

Representative specimens. PERSIA: Persia australis, s.l. s.d. *Aucher-Eloy* 4191 (K) (BM) (P); in rupibus ad monumentum Nakschi Rustam pr. urb. Schiras, May 1842 Kotschy 309 (E).

Distribution: Iraq, S. Persia.

In his Diagnoses (l. c.) Boissier described two species: *C. parviflora* and *C. mucronifolia*. I examined the specimens of *C. parviflora* cited in the Diagnoses (Aucher-Eloy 4191 and 4191A) and found them belonging to two different species: one representing a small-leaved variety of *C. leucophylla* with flowers of almost the same size and structure as in the latter and the other *C. mucronifolia*. In his Fl. or. Boissier has reduced both these species to a single variety var. *parviflora* referring to this variety some additional specimens which belong to *C. ovata* Desf. var. *microphylla* (Ledeb.) Zoh.

4. **C. mucronifolia** Boiss.

Diagn. Ser. 1, 1: 3 (1842). — *C. spinosa* L. var. *parviflora* Boiss. Fl. or. 1: 420 (1867) p.p. — *C. elliptica* Hausskn. et Bornm. ex Bornm. in Mitt. thür. bot. Ver., N.F. 6: 49 (1904).

Representative specimens. IRAN: Persia australis, s.d. *Aucher-Eloy* 4189 (P). ARABIA: Reg. Mascate, s.d. *Aucher-Eloy* 4192, 4190 (P).

Distribution: Arabia, S. Persia.

C. elliptica, described by Haussknecht and Bornmüller ex Bornm. in Mitt. thür. bot. Ver., N. F. 6: 49 (1904) and recorded by Bornmüller in Beih. bot. Zentralbl. 28, 2: 128 (1911), is no doubt identical with *C. mucronifolia* Boiss. Bormüller characterized this species "foliis brevipetiolatis anguste ellipticis vel oblongis, utrinque acuminatis, coriaceis et sempervirentibus". His specimens are without flowers. He adds (l.c.) two other varieties, var. *β stenophylla* Bornm. (foliis ca. 3–6 mm latis et 17–25 mm longis) from the Persian Gulf and var. *γ maskatensis* Hausskn. et Bornm. (foliis 15 × 20 vel 11 × 30 mm latis longis) from Maskat, Arabia.

The specimens collected by Aucher-Eloy (no. 4191A) and referred to by Boissier as *C. mucronifolia* vary in the same direction as pointed out by Bornmüller (l. c.). Although the leaves, especially the larger ones, are reminiscent of *C. cartilaginea* Decne., the flowers are entirely different, being much smaller and having sepals not hood-shaped.

5. **C. cartilaginea** Decne.

In Ann. Sci. nat. 2 Ser. 3: 273 (1835). — *C. sinaica* Duham. Nouv. 1: 144 (1801). — *C. galeata* Fres. in Mus. senckenb. 2: 111 (1837); Boiss. Fl. or. 1: 421 (1867).

Representative specimens. ARABIA: Dhofar, mountain desert in wadi, Jebel Qbris, 30.10.1943 *D.F. Vesey-Fitzgerald* 12772 (HUJ). PALESTINE: Arava Valley, Wadi Misr, 10.4.1952 *J. De Angelis* 128 (HUJ). IRAQ: Syrian Desert, 42 km W. of Ramadi 11.10.1933 *A. Eig* and *N. Feinbrun* 882 (HUJ).

Distribution: I have also seen specimens from Socotra, Egypt, Sinai, Afghanistan, Baluchistan.

This species has been named by Duhamel (l. c.) *C. sinaica*, but his description is very inadequate and includes in fact two different species, *C. cartilaginea* Decne. and *C. spinosa* L. var. *aravensis* Zoh. This is clearly seen from his references to Belon (Observ. singul. Liv. II, Chap. 60, 1553) and to Shaw (Cat. Pl. Afr. et Asiae, African specimen No. 112, 1738).

It is not clear on which specimen Duhamel based his description and thus *C. sinaica* should fall into the category of nomina ambigua and should be abandoned.

A form with heart-shaped leaves has been observed from Arabia, Riyadh, 660 m, 1937 *Dickson* 390 bis (K); Iraq, Jazira 1932, *Guest* 3821 (K; sine flores), but this appears not to be a constant characteristic, as there are also specimens with oblong and orbicular leaves on the same branch. There are also glabrous and pubescent forms.

6. **C. decidua** (Forsk.) Edgew.

In J. linn. Soc. 6: 184 (1862). — *C. decidua* (Forsk.) Pax in Engl. u. Prantl, natürl. Pflanzenfam.3, 2: 231 (1891). — *C. aphylla* Roth, Nov. Pl. Sp.: 238 (1821); Oliver, Fl. trop. Afr. 1: 95 (1868). — *C. sodada* R. Br. in Denham, Clapp. et Oudn. Trav. App. 20: 225 (1826). — *Sodada decidua* Forsk. Fl. aeg.-arab.: 81 (1775). — *Icon.*: Del. Fl. Egypt: t. 26 (1812, sub *Sodada decidua*).

Representative specimens. ARABIA: Wadi Haibar, edge of the bed, 20.2.1944 *Cort* 141 (HUJ). PALESTINE: Upper Jordan Valley, Ein Zarah, 15.5.1923 *I. Reichert* 132 (HUJ); Southern Negev, Wadi Khiani, 3.5.1956 *J. Lorch* 134 (HUJ).

Distribution: I have also seen specimens from Egypt, Iraq, Baluchistan, Sind.

THE VARIATION AND EVOLUTION OF THE GROUP

The six species of *Capparis* occurring in the Mediterranean and Near Eastern countries can be classed in two groups: one comprising *C. decidua*, *C. mucronifolia* and *C. cartilaginea*, and the other *C. spinosa*, *C. sicula* and *C. leucophylla*.

The species of the first group are tropical, notably Nubo-Baluchian, showing clear relations to tropical African species. In the area under review they are confined to hot deserts of the Red and the Arabian Seas. This type of distribution is common to scores of other tropical African species which penetrate the southern fringe of the Near Eastern deserts. To all our knowledge they are relics of an entire flora that dominated the region during the Late Tertiary. These tropical species show no relations to the other group of the local species nor are they related to each other.

The remaining three species are phylogenetically interrelated. Although they are also of tropical origin they have since lost their links with the tropical African stock and have developed independently within their present area.

A closer examination of the varieties of these species as to their evolutionary trends leads to an assumption that *C. spinosa* var. *aegyptia* is the most primitive form of

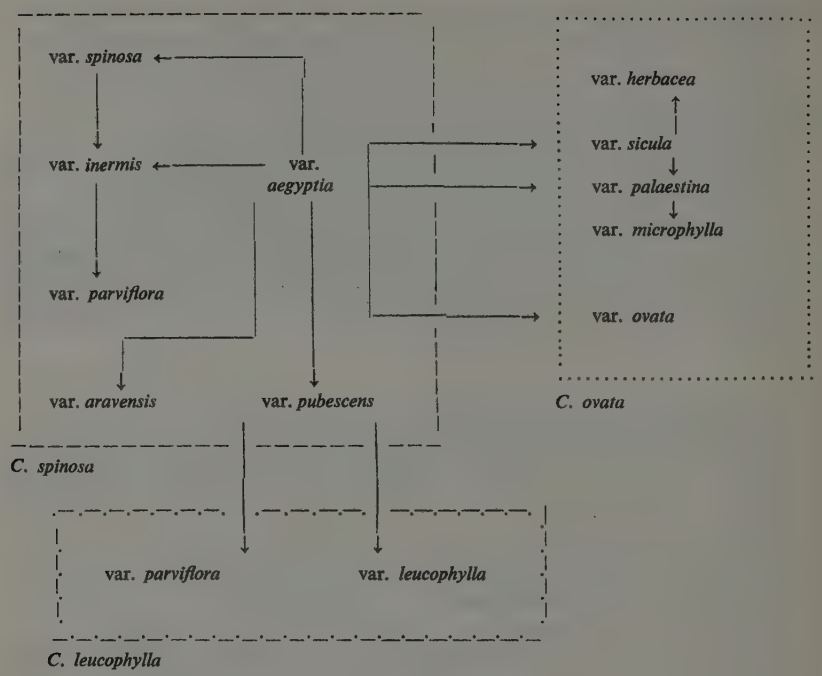

Figure 4

Evolutionary trends in the Mediterranean species of *Capparis*. (For explanation see text).

the whole group (Figure 4) for the following reasons: First, unlike other varieties it is found predominantly in primary habitats. Secondly, it exhibits a high degree of variability which embraces almost the whole gamut of variation within the group. It is limited mainly to the southern and south-eastern part of the Mediterranean area, and advances southwards and eastwards as far as the Sudanian and Eritreo-Arabian regions.

In Israel, var. *aegyptia*, although occurring in the Mediterranean territory, is never found in the typical Mediterranean communities. It is most abundant in the rather subtropical *Hyparrhenietea hirtae* class, inhabiting mainly the southern Coastal Plain and the adjacent hills. Otherwise it is bound to walls and rocks, being here certainly secondary.

From the findings of large-leaved and sometimes spineless forms of this variety on shady cliffs (Jordan Valley), I am inclined to believe that the mainly North-Mediterranean var. *spinosa* is a mesophytic ecotype of var. *aegyptia* which through

selection by man for larger flower-buds during centuries has considerably diverged from its original form. From its distribution in the North Mediterranean countries var. *spinosa* seems to be a cultigen which escaped from cultivation to other secondary habitats.

Var. *inermis* is another ecotype confined mainly to sea-shore cliffs and marked by its rather succulent leaves, its weak stipular spines, often lacking altogether, and its large flowers. These are characteristics common of coastal ecotypes. As a matter of fact, some intermediate forms have been found between the above mentioned varieties of the "spinosa" group. The small-flowered variety of this group (var. *parviflora* J. Gay), found in cultivation, is perhaps a "saut en arrière" towards the original form.

The other lines of evolution taking their issue from var. *aegyptia* lead to the "leucophylla" and the "ovata" groups. The very common glabrous and round-leaved "aegyptia" form is replaced at the southern fringe of the area by var. *pubescens* which approaches the "leucophylla" group by its indumentum. This group consists of two varieties, the large-leaved var. *leucophylla* (mainly in Iraq) and the small-leaved var. *parviflora* (in southern Iran). The scarcity of material of this very interesting group does not allow further comments on the nature and development of these varieties. The other trend, connected with the "oblongation" of the leaves, hairiness of the stem, leaves and flowers, as well as with stronger zygomorphy of the calyx and corolla, leads from var. *aegyptia* to the "ovata" group.

Of var. *ovata* itself, which is limited to NW Africa, I have seen in Morocco forms intermediate between var. *aegyptia* and var. *sicula*, most certainly of hybrid nature. Nevertheless, var. *ovata*, in its extreme form, is a "good" variety outstanding by its broad-ovate and somewhat leathery leaves with a truncate or heart-shaped base. It seems that this form has not been further differentiated and forms a blind alley in the whole complex. In contrast, var. *sicula* has a large range of distribution, almost encircling the Mediterranean, with the exception of the Syro-Lybian sector. Intermediate forms linking this variety with var. *aegyptia* are found mainly in North Africa and in Crete within the range of the latter. Var. *sicula* shows a number of smaller variants in leaf form and pubescence. The elliptical form occurring in Cyprus is especially worth mentioning. In Turkey and Iraq this variety becomes more pubescent and merges southwards and eastwards into var. *palaestina*. Var. *microphylla* is merely a small-leaved and small-flowered deviation from the former. A direct connection between var. *aegyptia* and var. *palaestina* is evidenced by the occurrence of intermediate forms between the two taxa (Arava Valley, Israel). Var. *herbacea* confined to the Caucasian-Armenian region and outstanding by its leaf form, its stipular spines as well as the shape of the petals, as evident from Marschall von Bieberstein's illustration, is none the less linked with var. *sicula* in northern Turkey and its vicinity.

The genetic nature of all the links and intermediates mentioned above, cannot

be revealed without experimental methods, but experimenting with these shrubs is exceedingly difficult and unpromising. Apparently some of these forms are hybrids, since, they are met with only in the overlapping areas of the respective taxa.

Mention should be made at this juncture of the pattern of variation within the frame of the "species" admitted here. Examples of parallel variations occurring in all species are: pubescence (*C. spinosa* var. *pubescens* and *C. ovata* var. *palaestina*), microphylly and micranthy (*C. spinosa* var. *parviflora* and var. *pubescens*, *C. ovata* var. *microphylla*), loss of stipular spines (*C. spinosa* var. *inermis* and *C. ovata* var. *ovata*). There is also an evolutionary trend from actinomorphous to zygomorphous structure of flower, well manifested in the *C. spinosa* var. *aegyptia* – *C. ovata* var. *sicula* line.

AN ECOLOGICAL AND PHYSIOLOGICAL STUDY ON SOIL FUNGI OF THE NORTHERN NEGEV (ISRAEL)

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ABSTRACT

A comprehensive study is given of 82 species of fungi isolated from the arid soils in the Northern Negev (Israel).

Most of these species have been found not to be specific to arid soils. A great number of them are cosmopolitan soil fungi. The genera *Aspergillus* and *Penicillium* are represented by a great number of species.

Some species of fungi were found in all kinds of soil investigated; others appeared in peculiar soils only.

Loess soils were found to be the richest, both in the number of fungi per gram earth and in the number of species. Hammada soils are less rich and sand soils are the poorest. These data stand in correlation with the quantity of organic matter in these soils and not with their humidity.

The quantitative study has shown that the number of fungi and Actinomycetes per gram earth in the Negev is very small in comparison with that known for cultivated soils. This number was not found to change with the season of the year.

The number of fungi diminishes with the depth. Investigation of the biochemical activity of 15 widely prevalent species showed that they are able to decompose gelatine, starch and cellulose. In testing for the optimal temperature for growth, it was found that some species of *Aspergillus* grow well and produce spores at 36°C while the optimal temperature for most of the other fungi was 26°C and their optimum for sporulation was at 30°C.

From the above can be seen that in the arid soils of the Northern Negev exists a rich fungus population which is suited to the special conditions of its habitat.

INTRODUCTION

Microscopic fungi found in the soil are very important as they decompose organic matter, stabilize soil structure, and are also known to be capable of supplying useful or harmful substances for other organisms. For this reason, since the end of the last century, soil fungi have been studied intensively and in various parts of the world. Most of the early papers in this field dealt only with their systematic aspects. Only in recent years have ecological and physiological qualities of soil fungi been considered. However, these latter studies, as well as the systematic ones, were carried out mainly on cultivated or fertile soils, and only a few of them deal with arid soils—sands, dunes, desert, heathland and calcareous soils*.

* LeClerg and Smith (1928), Killian and Feher (1939), Moreau M. and F. (1945), Fletcher and Martin (1948), Garrett (1950, 1955, 1956), Warcup (1951), Nicot (1953, 1955), McLennan and Ducker 1954a,b), Tresner et al. (1954), Park (1955), Saksena (1955), Sappa (1955), Nicholls (1956), Montégut 1956), Brown (1958), Apinis (1958).

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In the areas closer to Israel, studies on soil fungi have been carried out in Egypt (Sabet 1935, 1939; Ragab 1956), in Sudan (Nour 1956), and in India (Agnihothrudu 1955 a,b, 1957a,b, 1958; Saksena 1955) whose common factor with the soils of Israel is their high temperature.

We began our work on soil fungi in Israel on soils of the arid zones since Israel is located on the boundaries of great deserts, and quite a large part of the country itself is a desert. This investigation, which is the first of its kind in our country, follows the trend mentioned by Thornton (1952) at the International Symposium on Desert Research held in Jerusalem.

The systematic data on the fungi isolated are included in a paper by Rayss and Borut (1958). In the present paper, the soil fungi of the arid Northern Negev were studied qualitatively and quantitatively for their distribution in different soils, depths and seasons, and in particular for their physiological activity. From these data, we hope to elucidate whether this population is specific to arid soils and to what extent it is adapted to the special environmental conditions under which it is found.

MATERIALS AND METHODS

1) *Collection of the soil samples*

In each locality a hole was dug to the depth of about 50 cm (except in cases where it was technically impossible). These holes were dug as distant as possible from roots of higher plants in order to eliminate the effect of the rhizosphere. At the right depth the area was cleaned with a spatula sterilized by dipping it in alcohol and burning. A sterile test tube was then horizontally pushed into the soil, and when enough material was collected the test tube was withdrawn and plugged with a sterile cotton plug. In each case the deepest sample was taken first. All the test tubes from each locality were wrapped in paper and transferred to the laboratory.

2) *Diluting, plating, counting and isolating*

From each sample, 1 g was weighed out under sterile conditions and a dilution of 1 : 100 was prepared in a solution of NaCl 0.75% W/V. From this dilution, 0.5 cc of liquid was withdrawn with a sterile pipette into Petri dishes containing the following media:

1) Conn's sodium asparaginate glycerol agar (Fred and Waksman 1928)

2) Poor Sabouraud's agar (2 g glucose, 1 g peptone, 20 g agar, 1000 cc tap water)

3) Poor Sabouraud's agar—as medium 2 above, only 1000 cc earth extract were used instead of the 1000 cc tap water. (For this medium earth extracts of soil from each locality were prepared and the soil suspension from each locality was inoculated onto the plate containing the corresponding earth extract).

The above media were selected after a series of experiments because they permit the growth of most fungi. Two plates of each medium were used for each sample — 6 in all. After the media had solidified, the soil suspension was added to the plates

and was dispersed with the aid of a Drygalsky needle. This method gives better results than a method of adding the suspension to a melted agar (Paharia and Kommedhal 1956). The plates were incubated at room temperature during the summer, and in a 26°C incubator during the winter. Fungi and actinomycetes were counted under a binocular dissecting microscope after 14 days. The plates were reexamined after another fortnight, by which time the slow growing forms should have appeared. Isolations were inoculated into plates with potato–dextrose agar (P.D.A.) and after pure culture was obtained, they were transferred to P.D.A. slants.

Most of the Penicillia and the Aspergilli were identified on Czapek's agar (Thom and Raper 1945) and malt extract agar (Raper and Thom 1949), *Cunninghamella* on M.D.A. (Cutter 1946), the other fungi on P.D.A.

3) *Physiological studies*

The ability of the fungi to liquify gelatin was examined on gelatin medium and the decomposition of starch was examined on starch agar (Baldacci et al. 1957). The zone of enzymatic activity was established by adding lugol solution to the plates. The ability to decompose cellulose was examined on media containing salt solution and, as a source of cellulose, membranes of *Acetobacter xylinum* (Aschner 1937) or discs of Fisher lens paper No. 11–996 were used.

The optimal growth temperature was investigated by measuring the diameter of the fungus colony on plates containing Czapek's medium according to the method of Brancato and Golding (1953).

DESCRIPTION OF THE LOCALITIES EXAMINED

Eight typical localities in the Northern Negev were chosen, all of them located in the Irano–Turanian and Saharo–Sindian territories of Israel (Eig 1938). For convenience, they were chosen along the Beersheva–Sdom road (Table I). In this paper each sample will be designated by its respective locality number (appearing in the first column of Table I) and by its depth (as represented by the letters in the last column of Table I). The chemical and physical properties of the soil samples are given in Table II.

From each locality, samples were collected on 6 different occasions on the following dates: 17th May 1953, 22nd September 1953, 16th December 1953, 10th April 1954, 2nd November 1954, 16th March 1954. (The results of the first trip are not given here, as the samples taken then served for establishing the working methods).

The *p*H values were measured on each trip, and from the third trip on, soil humidity was also estimated (Table III).

From Tables II and III, it can be seen that the soils have a basic reaction and very low humidity. The latter shows seasonal fluctuations. The organic matter content is also very low, especially in locality 3, and the total salt content is very high, especially in the salines (localities 7 and 8).

TABLE I

Description of the localities examined

Locality No.	Locality	Soil type	Plant association	Depth in cm a	b	c
1	Mishmar Hanegev	Loess	*Achilleetum santolinae*	10	25	35
2	Beersheva	Loess	*Achilleetum santolinae*	10	25	45
3	12 km south of Beersheva	Sand-dune	*Artemisia monosperma–Aristida scoparia* ass.	10	25	50
4	Tureibe. 32 km to Sdom	Sandy plain	*Retama roetam–Anabasis articulata* ass.	10	25	50
5	Hammada A — 22 km to Sdom	Hammada	*Zygophylletum dumosi* (dense)	20	35	—
6	Hammada B — 12 km to Sdom	Hammada	*Zygophylletum dumosi* (sparse)	15	30	—
7	2 km south of Sdom	Saline	*Nitrarietum retusae*	10	25	50
8	2 km north of Sdom	Saline	*Salsoletum rosmarini*	10	25	50

TABLE II

Physical and chemical properties of soil samples

Sample	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Calcium carbonate (%)	Total salts content (%)	Total nitrogen (%)	Organic matter content (%)
1a	22	64.9	9.5	5.5	17.9	0.043	0.057	0.56
1b	2	55.5	7.3	12.1	23.1	0.043	0.028	0.53
1c	1.1	48.8	7.4	14.0	28.7	0.080	0.018	0.29
2a	0.1	57.5	9.8	5.7	26.9	0.110	0.021	0.34
2b	0.2	50.7	11.3	7.2	30.6	0.240	0.016	0.29
2c	0.2	51.2	10.8	7.0	30.8	0.680	0.014	0.25
3a	52.6	43.3	0.3	2.0	1.8	0.030	0.001	0.04
3b	44.8	49.9	0.3	2.0	3.0	0.032	0.001	0.06
3c	51.5	44.5	0.2	1.4	2.4	0.025	0.001	0.06
4a	84.8	8.3	0.9	2.0	4.0	0.030	0.010	0.17
4b	82.0	11.8	0.9	1.7	3.6	0.032	0.010	0.15
4c	77.0	14.8	1.5	2.1	4.6	0.021	0.007	0.15
5a	8.0	45.0	13.0	4.0	30.0	0.225	0.030	0.61
5b	6.9	42.4	11.0	7.3	32.4	0.320	0.030	0.80
6a	1.8	56.3	14.0	6.0	21.9	0.550	0.020	0.26
6b	1.4	60.8	11.0	8.7	18.1	0.650	0.010	0.21
7a	1.9	59.9	5.7	5.5	27.0	21.500	0.130	4.11
7b	2.0	52.1	6.0	7.5	32.4	13.250	0.050	1.77
7c	1.1	50.6	7.8	6.7	32.8	11.000	0.050	1.94
8a	25.1	27.7	1.5	2.2	43.5	3.200	traces	0.40
8b	18.2	28.4	2.7	3.8	46.9	2.20	0.020	0.39
8c	25.0	19.2	2.0	2.8	51.5	1.65	0.010	0.26

TABLE III

pH and humidity (in %) of the soil samples taken during the different trips

Soil sample	September 1953	December 1953		April 1954		November 1954		March 1 1955	
	*p*H	*p*H	Hum.	*p*H	Hum.	*p*H	Hum.	*p*H	Hum.
1a	8.9	8.3	14.05	8.2	5.27	8.1	1.67	8.9	3.95
1b	8.4	8.6	10.03	8.4	5.10	8.5	0.87	8.4	6.17
1c	8.4	8.7	7.44	8.4	4.58	8.4	4.18	8.3	6.21
2a	9.0	8.6	9.34	9.4	8.03	8.4	0.61	8.8	4.88
2b	9.2	8.5	13.32	9.2	7.03	8.4	3.15	9.0	6.08
2c	9.1	8.2	8.86	8.4	9.32	8.6	3.06	9.1	6.50
3a	8.4	8.8	3.43	8.8	2.41	8.2	0.35	8.0	1.55
3b	8.2	8.7	3.17	8.8	1.82	8.2	0.42	8.5	0.77
3c	8.6	8.7	0.11	8.8	1.73	8.2	0.54	8.4	2.37
4a	8.6	8.5	0.13	8.9	4.10	8.4	0.43	8.6	1.09
4b	8.5	8.7	0.67	8.9	6.24	8.2	0.54	8.4	1.87
4c	8.6	8.8	1.03	8.9	6.38	8.3	0.59	8.5	1.80
5a	8.3	8.0	2.60	8.7	9.53	8.3	1.45	8.9	7.35
5b	8.5	8.3	4.52	8.7	8.25	8.4	3.12	8.8	7.39
6a	7.4	7.6	5.01	7.4	12.03	7.2	5.64	7.2	12.69
6b	7.4	7.7	5.47	7.4	11.54	7.5	7.42	7.4	10.19
7a	7.9	7.9	10.83	8.0	17.35	7.3	17.95	7.6	17.71
7b	7.9	7.7	15.21	7.8	16.34	7.3	16.00	7.6	17.09
7c	7.8	7.5	14.74	7.8	14.48	7.3	17.76	7.7	18.86
8a	7.7	7.7	2.18	8.4	2.91	7.9	0.42	7.4	2.32
8b	7.4	7.6	4.17	8.2	1.96	7.9	0.47	7.5	4.16
8c	7.8	7.6	4.57	8.2	1.49	7.9	0.56	7.5	1.46

RESULTS AND DISCUSSION

1) *Quantitative results*

For each soil sample, except those from localities 7 and 8, the numbers of fungi and Actinomycetes per 1 g dried soil were calculated (Table IV). For localities 7 and 8 (the salines), no quantitative results were obtained, as the saline fungi grew very badly on the media used — only little and occasional growth being observable.

From Table IV the following results can be seen:

The numbers of fungi vary between 100 – 16,800 per 1 g of soil. These numbers are very low in comparison with those known from other regions or cultivated soils where the numbers vary between 10,000 – 100,000. This is not surprising if we consider the limiting factors in our soils, i.e. high temperature, low humidity and a low organic matter content.

TABLE IV

Numbers of Fungi and Actinomycetes per 1 g of soil (Dry weight)

Locality	September 1953		December 1953		April 1954		November 1954		March 1955	
	Fungi	Actino-mycetes	Fungi	Actino-mycetes	Fungi	Actino-mycetes	Fungi	Actino-mycetes	Fungi	Actino-mycetes
1a	1800	4600	3800	200	3400	4200	2000	12000	1500	6200
1b	700	8400	1400	800	1400	9800	1400	5400	4600	5400
1c	2200	7000	2600	1000	2100	5000	600	7800	1400	2000
2a	1800	4600	8400	—	2500	5200	3500	16800	6000	20000
2b	700	2800	800	1000	2000	2600	900	12400	1700	3000
2c	3800	1000	400	2000	700	2800	2100	21600	600	3000
3a	1200	7400	16800	600	200	1000	400	18600	200	2600
3b	400	4400	1600	6000	100	2000	1000	10400	200	20000
3c	1000	7400	900	3400	100	400	200	13800	40	—
4a	2000	6200	1000	5800	500	7200	400	7600	1800	5400
4b	3800	2400	10400	2800	100	5200	100	5400	400	3200
4c	800	5800	5200	3800	240	4400	120	9600	400	3400
5a	2000	3000	1500	2600	500	600	400	8200	400	2600
5b	2000	5600	900	1000	1200	1000	200	5200	1400	7000
6a	1400	3400	7200	3600	1240	5800	—	—	—	600
6b	2600	8000	1600	2800	4000	4000	100	200	100	400

The numbers of Actinomycetes per 1 g of soil vary between 100–20,000. Once again, in comparison with cultivated soils this range is very low. However, our numbers for this group are somewhat higher and the differences between samples smaller than those we obtained for fungi. The Actinomycetes seem to be stable organisms which multiply especially during the dry season when the majority of fungi and bacteria have been destroyed or entered into resting stages.

No significant correlation between the number of fungi present and soil humidity could be found. This may be due to the limitation of the dilution plate method which does not distinguish between the active fungi and the spores and other resting organs or to some other untested limiting factor.

An especially high count of fungi was obtained in some samples collected in December 1953, but this was due to the domination of one or several species of *Penicillium* on the plates. It seems that on this particular trip these species readily sporulated and a scattering of a chain of conidia on the plate surface caused the appearance of many colonies of this genus.

The number of fungi is more or less constant for each locality and shows no great variation at the time of sampling. The two loess localities — Beersheva and Mishmar Hanegev — give the highest and most stable counts. The next highest counts were made from the hammadas, and the smallest numbers came from the sandy dunes of

Tureibe. The decrease in numbers corresponds to the amount of organic matter in the soil with the exception of locality 5, a hammada, in which the number of fungi is lower than in the loess, although the organic matter content is higher. This may be a result of the high salt content in this locality. The sporadic occurrence of high numbers in the sand localities may be due to the occasional presence of organic residues in the soils.

With regards to the vertical distribution, the samples taken nearest to the surface gave the highest counts, and generally the numbers decreased with increase of depth. These data are in agreement with what is known from other parts of the world.

2) *Qualitative results*

In the course of this work, 82 species belonging to 34 genera were isolated and identified. Some of these species had never been found in soils previously; some were found but rarely and the majority are known to be typical soil fungi. A detailed list of species and their occurrence in the different localities is given in Table V. Four of the species belong to the Phycomycetes, 43 belong to the Ascomycetes and 35 to the Deuteromycetes. Among the Ascomycetes, 3 species are of the Gymnoascaceae; *Penicillium* was represented by 21 species, 3 of them producing perithecia; *Aspergillus* by 14 species, many of them forming abundant sclerotia.

Four species of the Deuteromycetes are of the Sphaerioidaceae, 6 of the Mucedinaceae, 18 of the Dematiaceae, 2 of the Stilbaceae, 3 of the Tuberculariaceae and 3 were Mycelia sterilia. An annotated systematic study concerning these fungi has been published (Rayss and Borut 1958).

Some isolates of Actinomycetes were sent for identification to Prof. Baldacci of Milano and have been studied by him thoroughly (Baldacci et al. 1957).

Careful examination of the fungi occurring on the dilution plates revealed that many of the 82 species occurred only once, i.e. in one locality or one trip and in low numbers. Others were more abundant and appeared in several localities. Figure 1 and the list given below describe the distribution patterns of the most common or interesting fungi:

1) *Alternaria:* species were common especially in the loess and hammada soils, very few in the sandy dunes.

2) *Aspergillus fumigatus:* appeared in high numbers in the soils of the Tureibe and the two hammadas, and only one colony was obtained from Mishmar Hanegev. The majority of isolates were obtained from depths of 10–30 cm.

3) *A. niveus:* occurred in low numbers in the hammadas and only once in Mishmar Hanegev. In all cases it was isolated only from depths of 25–50 cm.

4) *A. sulphureus:* occurred in high numbers at all depths tested in loess soils, especially in Mishmar Hanegev and a few colonies were also obtained from the hammadas. During this research this fungus was never isolated from sandy soils.

5. *A. versicolor:* occurred in all localities tested in low numbers.

6. *Cephalosporium:* the commonest species of this genus, *C. acremonium* and also other species of *Cephalosporium* occurred many times in localities 1–5 and were absent in locality 6 (hammada). The highest numbers were obtained from the sand-dunes of locality 3.

7. *Chaetomium gangligerum:* many colonies were obtained during the various trips and it was especially common in the loess soils.

8. *Ch. succineum:* the distribution of this species resembles in general that of *Ch. gangligerum.* However, it occurred in the highest numbers in the hammada of locality 6 and was not found in the loess soil of Mishmar Hanegev.

9. *Eidamella deflexa:* occurred in low numbers only in 3 localities (Table V). The richest of these was hammada of locality 6. Most of the colonies were observed on the dilution plates of December 1953.

10. *Fusarium:* species of this genus occurred in all soils and depths examined except locality 6. The highest numbers were obtained from the sand-dunes of locality 3. In general the distribution pattern of this genus resembles that of *Cephalosporium.*

11. *Gymnoascus reessii:* the highest numbers were obtained from the loess soil of Beersheva. The distribution pattern of this species resembles in general that of *Chaetomium gangligerum.*

12. *Hormodendrum:* species of this genus were found in different localities during all the trips. The highest numbers were obtained from the loess soil of Beersheva.

13. *Mycelia sterilia:* dark and hyaline sterile mycelia were obtained from all the localities, throughout this research. Hyaline mycelia were more common than the dark ones, especially in the two loess localities. Dark mycelia were obtained in high quantities from the sandy dunes of locality 3 and were not found in the loess soil of Beersheva.

14. *Myxotrichum emmonsii:* few colonies were present in samples taken at Beersheva on two separate trips. These were obtained from the depths of 10 and 25 cm.

15. *Penicillium citrinum:* among the Penicillia this species was the most common and was present in samples taken from all localities on all trips. It was found at all depths and the highest counts were made from the sandy dunes.

16. *Penicillium corylophilum:* appeared in high numbers in two hammada soils. Few colonies were found in loess soil of Mishmar Hanegev.

17. *Penicillium egyptiacum:* this ascospore forming species occurred in high numbers at all depths of loess and hammada soils and was not found in sandy soils. (Two other ascospore forming Penicillia: *P. baarnense* and *P. levitum*—were found only in the sandy soil of Tureibe).

18. *Penicillium janthinellum:* this typical soil-fungus occurred at all depths in only 3 localities (Table V). High numbers were obtained from the loess soil of Mishmar Hanegev.

19. *Penicillium jenseni:* obtained from loess and sandy soils mostly from Beersheva and not found in the hammadas. Its numbers decrease with increasing depth.

20. *Penicillium lilacinum:* few colonies of this species were obtained from all localities (except locality 3, the sandy dunes) and during all trips. The highest counts were made from loess localities.

21. *Rhizoctonia:* isolates of this genus were found during all the trips, especially in the two sandy soil localities.

22. *Stachybotrys atra:* found only in the loess and sandy soils. Highest counts were obtained from the sandy soil of the Tureibe.

23. *Stemphylium verruculosum:* occurred in low numbers only in four localities (Table V).

24. *Tilachlidium humicola:* was found only in the two loess localities and the higher count was made from Beersheva.

TABLE V

Occurrence of fungi in samples of the Negev soils

Name of organism	Locality							
	1	2	3	4	5	6	7	8
PHYCOMYCETES								
MUCORACEAE								
Actinomucor corymbosus		+						
Rhizopus nigricans		+						
CHOANEPHORACEAE								
Cunninghamella bainieri	+							
C. bertholletiae						+		
ASCOMYCETES								
GYMNOASCACEAE								
Eidamella deflexa		+		+		+		
Gymnoascus reessii	+	+		+		+		
Myxotrichum emmonsii		+						
ASPERGILLACEAE								
Aspergillus flavipes	+	+						
A. flavus	+							
A. fumigatus	+			+	+	+		+
A. melleus		+				+		
A. niger	+							
A. niveus	+				+	+		
A. ochraceus		+						
A. quercinus				+				
A. sclerotiorum	+	+						
A. sulphureus	+	+			+	+		
A. terreus	+				+			
A. ustus	+					+		
A. versicolor	+	+	+	+	+	+		
A. wenti		+						
Penicillium atramentosum				+				
P. baarnense				+				
P. brevicompactum	+							
P. chrysogenum				+				+
P. citrinum	+	+	+	+	+	+		
P. corylophilum	+				+	+		
P. egyptiacum	+	+			+	+		
P. frequentans	+							
P. fuscum						+		
P. janthinellum	+			+	+			
P. jenseni	+	+	+	+				
P. lanosum	+							
P. levitum				+				
P. lilacinum	+	+		+	+	+		
P. melinii					+			
P. miczynskii		+						
P. multicolor	+							
P. ochrochloron	+							
P. oxalicum	+							
P. raciborskii		+						
P. steckii	+							
Thielavia terricola			+					
OPHIOSTOMATACEAE								
Microascus trigonosporus	+	+		+				

TABLE V (Continued)

Name of organism	Locality							
	1	2	3	4	5	6	7	8
CHAETOMIACEAE								
Chaetomium gangligerum	+	+		+		+		
Ch. succineum		+		+		+		
XYLARIACEAE								
Rosellinia winteriana						+		
DEUTEROMYCETES								
SPHAERIOIDACEAE								
Coniothyrium rude					+			
C. subcrustaceum		+						
Phoma sp.				+		+		
Sphaeronema sp.		+						
MUCEDINACEAE								
Cephalosporium acremonium	+		+	+	+			+
C. asperum		+						
C. curtipes		+						
C. humicola	+		+					
Spicaria violacea	+							
Tritirachium album						+		
DEMATIACEAE								
Alternaria geophila	+	+				+		
A. grisea							+	
A. humicola	+				+			
A. tenuis	+	+				+		
Botryotrichum piluliferum			+					
Cladosporium sp.	+							
Hormodendrum cladosporioides			+			+		
H. hordei	+							
H. nigrescens						+		
H. olivaceum				+	+			
H. resinae		+						+
H. viride			+	+				
Periconia pycnospora		+						
Stachybotrys atra	+	+	+	+				
Stemphylium verruculosum	+	+		+	+			
Torula lucifuga				+				
Zygodesmus sp.				+				
STILBACEAE								
Styzanus medius	+							
Tilachlidium humicola	+	+						
TUBERCULARIACEAE								
Fusarium sp.	+	+	+	+	+			
Myrothecium roridum						+		
M. verrucaria	+							
MYCELIA STERILIA								
Rhizoctonia	+		+	+	+			
Sclerotium		+			+			
Sterile mycelia	+	+	+	+	+	+		
Total number of species for each locality	43	35	13	27	20	25	1	4

By counting the number of species appearing in each locality it was found that localities which had a high total count per 1 g contained also a high number of species. Also the number of species in each locality is in correlation with the organic matter content of the soil. Therefore loess soils are the richest in total number of species present and are followed by the soils of Tureibe, the hammadas and the sand-dunes respectively (Table V).

3) *Physiological characteristics of the most common fungi*

The ability of 15 common species to decompose proteins (gelatin), starch and cellulose was investigated (Table VI). All fungi examined were found to be capable of liquifying gelatin, and all, except 2 species of *Chaetomium*, decomposed starch. Most of these fungi decomposed cellulose and the most efficient of them were the two species of *Chaetomium* and *Stachybotrys atra*. This proves that the most common species in our arid soils can decompose and use a large variety of organic substrates.

The same 15 species were also tested for their ability to grow and develop at temperatures varying from 15°C to 40°C (Table VI, Figures 2, 3, 4). It was found that certain species of *Aspergillus* were the most thermophilous fungi with an optimum growth temperature of 36°C. The optimum temperature for several other species was found to be 30°C, while the majority of fungi examined thrived best at 26°C. *Aspergillus sulphureus*, *A. niveus*, *A. fumigatus* and *Penicillium lilacinum* can grow even at 40°C, whereas others germinate but do not grow at this temperature.

TABLE VI

Physiological characteristics of 15 *species*

Name of organism	Optimal growth temperature	Optimal sporulation temperature	Zone of enzymatic activity on starch (in mm)	Liquifaction of gelatin	Cellulose decomposition
Alternaria tenuis	26°C	30°C	2	+++	+
Aspergillus fumigatus	36°C	36°C	3	+++	+
A. niveus	36°C	36°C	6	++	++
A. sulphureus	30°C	36°C	6	+++	+
A. versicolor	26°C	30°C	11	+++	±
Chaetomium gangligerum	30°C	30°C	0	++	+++
Ch. succineum	26°C	30°C	0	++	+++
Hormodendrum hordei	20°C–26°C	30°C	2	+++	—
Penicillium citrinum	26°C	30°C	10	++	+
P. egyptiacum	26°C	30°C	6	++	++
P. janthinellum	26°C	30°C	5	++	—
P. jenseni	26°C	30°C	3	++	±
P. lilacinum	26°C	30°C	2	+	—
Stachybotrys atra	26°C	30°C	3	++	+++
Stemphylium verruculosum	26°C	30°C	3	++	+

— no decomposition; ± doubtful decomposition; + weak decomposition; ++ medium decomposition; +++ strong decomposition.

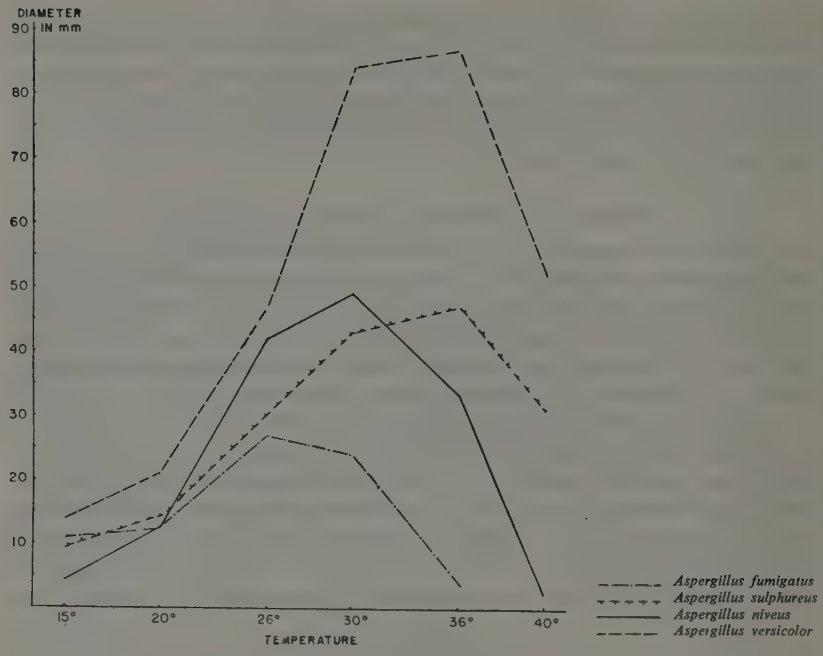

Figure 2
Growth of *Aspergillus* species at various temperatures

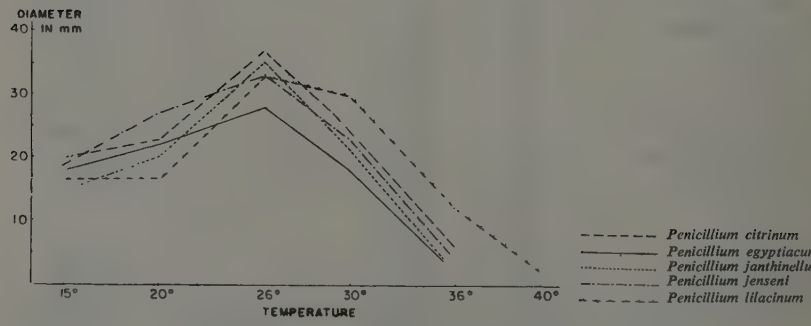

Figure 3
Growth of *Penicillium* species at various temperatures

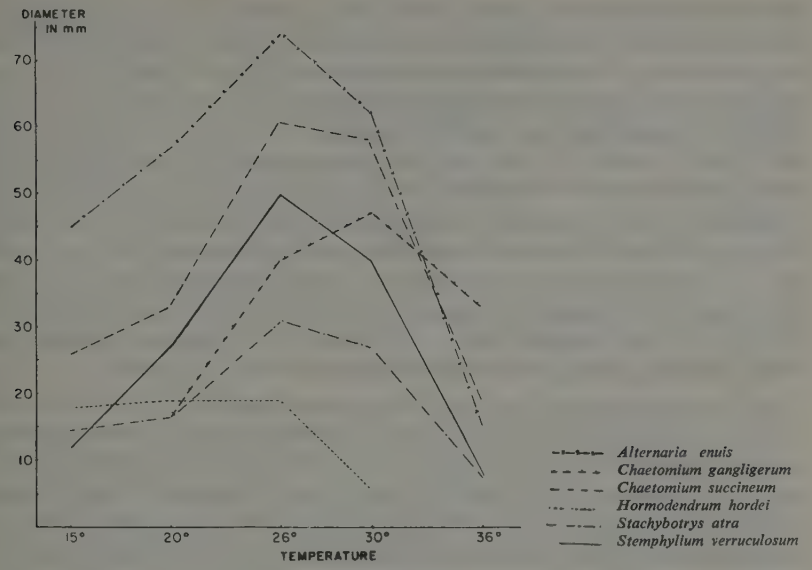

Figure 4
Growth of *fungis* species at various temperatures

The majority of species examined did not lose their vitality after being exposed to 40°C for 8 days, and continued to develop normally when transferred to room temperature. Exceptional temperature relations were shown by *Hormodendrum hordei*, which failed to grow at 36°C, and grew poorly at 30°C. The possible reason for this behaviour might be that this species is in reality a facultative parasite and not a soil fungus and had been introduced into soil with decaying host plants. Sporulation of all species examined was highest at a temperature of 30°C. All these fungi may be assumed to develop well at the depth from which the samples were taken as the soil temperatures at such depths do not exceed the ones quoted above (Ashbel 1950).

CONCLUSIONS

In this study an attempt was made to characterize the fungal flora in the arid soils of the Northern Negev.

We found that the soils examined contain a fungus population rich in species representing most of the fungal groups. Most of the species appearing in the Northern Negev are world-wide in their distribution and had previously been found in soils. Various phytopathogenic fungi were also found, for which the soil serves as a reservoir in which part of their life cycle is spent in the absence of their hosts

(*Sclerotium*, *Sphaeronema*, *Phoma*, *Fusarium*, *Coniothyrium*, *Rhizoctonia*, etc.). Furthermore, typical soil fungi which are pathogenic to animals were found (*Gymnoascus*, *Microascus*, *Myxotrichum*) as well as species which are usually isolated from seeds and dung. Therefore one gets the impression from the above data that the mycoflora of the arid soils does not differ qualitatively from the mycoflora of other soils. *Penicillium* and *Aspergillus* were the dominant genera, but quite a few Dematiaceae and Ascomycetes with resting organs were found. This is similar to the composition of the soil mycoflora of Egypt (Sabet 1935, 1939; Ragab 1956), Sahara (Killian and Feher 1939), Sudan (Nour 1956) and India (Saksena 1955). An interesting fact is the similarity of the conidial morphology between the species of *Coniothyrium* and *Phoma* isolated by us from the soil and those described on their respective hosts from the Mesopotamian deserts by Bubak (1914). The other species did not differ in their morphology from those isolated from other soil habitats.

The quantitative aspect of this work shows that the numbers of fungi per 1 g of soil are very low in comparison with fertile or cultivated soils. This is undoubtedly a result of the unfavourable environment. The numbers of fungi did not fluctuate during the various seasons of the year and it appears, therefore, that the factor determining the number of fungi in the fungal population is determined by the amount of organic matter in the soils and not by its humidity. A similar conclusion was also reached by Brown (1958) and others. In accordance with the above, the richest soils in total number of fungi, number of species and organic matter are the loess soils, next are hammadas and last the sandy soils, especially the sand dunes.

Most of the fungi found have a high sporulating ability or possess resistant resting organs; they are able to decompose a range of organic media and grow well at temperatures above 25°C. All these characteristics enable them to grow and multiply in their poor biotope. The soil fungi of deserts, therefore need not be looked upon as specialized populations—a conclusion also reached by Nicot (1953) in her work on desert sands. They include many cosmopolitan species and also comprise species with a more limited distribution, all being well adapted to their biotope because of the characters enumerated above.

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TOXICITY AND ANTIBIOTIC PROPERTIES OF SOME FUSARIA

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ABSTRACT

The results of investigation of toxicity in over 500 strains of *Fusarium* are presented. These strains were isolated from cereals growing in the Orenburg district, USSR, during the years 1943–49, which, not having been harvested in time, had been left under snow cover during the winter. The majority of strains belonged to the species *Fusarium poae* and *F. sporotrichioides*. Toxicity was studied by an application of fungus extracts to the bare skin of rabbits, and also by feeding fungus extracts to mice, guinea pigs, cats, horses and other animals. Data of the antibiotic activity of some *Fusarium* fungi are presented. Experiments showed that some *Fusarium* strains are antibiotically active with regard to *Mycobacterium tuberculosis*, *B. typhi abdominalis*, *B. paratyphi* B, *B. dysenteriae*, as well as *Staphylococcus aureus*.

In 1942 cases of a disease designated as septic *angina* (or in Russian, "alimentary–toxic aleukia") were registered in the Tshkalov (now Orenburg) district of the USSR. It was found that the disease is connected with the use of foodstuffs containing cereals which were left under snow during the winter. The disease appeared during six successive years, subsiding and then flaring up again with new force in various parts of the district.

Mycological investigations have been carried out on the grains and vegetative parts of cereals left under snow during the winter as well as on the soil on which the cereals were grown. The material was collected from trial fields layed out for this purpose in various parts of the Tshkalov district some of which were infested, while the others were free of the disease.

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Among the moulds found in the cultures the percentage of *Fusarium* species was fairly high. Over 500 cultures of *Fusarium* were isolated and identified. On these the toxicity and antibiotic activity of the fungi was studied.

METHODS

For a study of toxicity, pure cultures of *Fusarium* species were grown on the following media: acid potato agar, dextrose potato agar, malt agar, carbohydrate peptone agar, solid synthetic Czapek medium, as well as mould-free millet, wheat, and barley and millet husks. The cultures were placed, each species separately, in 3 litre flasks on the walls of which a layer of agar had been deposited by rolling, in Roux flasks, and in flasks containing 50–100 grams of wet grain. For a period of 15–35 days the *Fusarium* was grown at various temperatures ranging from 10°C to 25°C. The grown cultures were sterilized at a pressure of 0.5 atm for 15–20 minutes, or were steam sterilized for 1 hour. They were then taken out and dried at 45–50°C or in an oven at 70–80°C. Subsequently they were extracted in ether or 96% ethyl alcohol. The extracts were twice tested for toxicity on the bare skin of rabbits by a special method adopted by the author. The general toxic effect of Fusaria was also studied by feeding animals with pure agar cultures, dry fungi or fungus filtrates, as well as grains infected with individual *Fusarium* species.

The cultures' antibiotic activity was tested on a liquid carbohydrate–peptone medium and on solid synthetic Czapek medium, i.e. by the same method applied by the author in testing other fungi (Joffe 1956).

Cultures were grown in 250 cc Erlenmeyer flasks. The culture liquid was decanted after 7–8, 11–12, 14–15 and 21–23 days of fungus cultivation respectively, and passed through a Seitz filter.

The action of these fungus-filtrates on *Mycobacterium tuberculosis* was studied on an egg medium of Petraniani and on a 5% glycerine calf bullion, as well as on microbes of the intestine group and *Staphylococcus aureus* in Petri dishes on meat–peptone–agar, and by serial dilutions in a meat–peptone boullion with 1% glucose.

EXPERIMENTAL RESULTS

For an evaluation of the role of Fusaria in toxin production it seemed necessary to study the toxicity of isolated cultures. Among 501 *Fusarium* cultures isolated from the above mentioned substrata, 179 (35.19%) showed toxicity of varying degrees; there were 22.35% of toxic and highly toxic — and 13.37% of slightly toxic strains.

The results of toxicity investigation of *Fusarium* cultures by means of the skin test on rabbits are given in Tables I, II, III, and characteristics of the isolated *Fusarium* cultures according to species, substrate, place and time of isolation are shown.

Table I presents 61 cultures of *Fusarium sporotrichioides* Sherb. 44 of them were found to possess toxic or highly toxic properties, whereas 17 cultures showed mild toxicity.

TABLE I

Characteristics of Fusarium sporotrichioides *Sherb. strains**

No. of culture	Toxicity of cultures L	O	H	Year of isolation	Culture medium	Toxicity of original host	Original host	County of collection
332	+	+		1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
684		+		1945	Millet PD C	non-toxic	millet	Orenburgskij
752		+		1946	Millet, wheat PD	toxic	wheat	Orenburgskij
901	+	+		1946	Millet, barley C	non-toxic	rye	Buguruslanskij
956	+	+		1947	Millet, wheat PD	non-toxic	wheat	Orenburgskij
976	+	+		1947	Millet, barley AP M C	weakly toxic	millet	Orenburgskij
977	+	+		1947	Millet, barley AP M C	weakly toxic	millet	Orenburgskij
1049		+		1947	Millet, wheat C	non-toxic	wheat	Orenburgskij
1067	+	+		1947	Millet C-P C	non toxic	soil	Orenburgskij
1184		+		1947	Millet, wheat PD	non-toxic	wheat	Orenburgskij
1206		+	+	1947	Millet, barley C	non-toxic	millet	Orenburgskij
1264		+		1947	Millet, barley PD C	non-toxic	v.p. of pl. wheat	Orenburgskij
1307	+	+		1947	Millet, wheat PD	non-toxic	wheat	Orenburgskij
1682	+	+		1948	Millet, wheat PD	toxic	wheat	Orenburgskij
1684		+		1948	Millet C-P C	weakly toxic	soil	Dombarovskij
2384	+	+		1948	Millet, barley AP C	non-toxic	barley	Orenburgskij
358		+	+	1944	Millet, barley M C	toxic	millet	Orenburgskij
60/10		++	++	1944	Millet, barley AP M C	highly toxic	millet	Sol-Iletskij
341	++			1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
342	++	+		1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
343	++	++		1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
347		++	++	1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
349	++			1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
351		++	+	1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
738		+++	++	1946	Millet, barley C	highly toxic	millet	Alexandrovskij
740		++		1946	Millet, barley C	highly toxic	millet	Alexandrovskij
855		+++	+++	1947	Millet, barley AP M C	non-toxic	v.p. of pl. millet	Orenburgskij
920		++		1947	Millet, barley	non-toxic	millet	Sakmarskij
921		+++	++	1947	Millet, barley	highly toxic	rye	Zianchurinskij
955	+	++		1947	Millet, barley AP C	toxic	barley	Orenburgskij
1000		+++	++	1947	Millet, barley AP C	weakly toxic	millet	S.-Karmalinskij
1012		+++	++	1947	Millet, barley AP M C	non-toxic	millet	Orenburgskij
1070		+++	++	1947	Millet, wheat PD C	non-toxic	wheat	Orenburgskij
1072		+++	+++	1947	Millet, wheat PD C	non-toxic	wheat	Orenburgskij
1122	++	+		1947	Millet, wheat PD C	non-toxic	wheat	Orenburgskij
1139		++		1947	Millet, wheat PD C	non-toxic	wheat	Orenburgskij
1182		++	++	1947	Millet, wheat PD C	weakly toxic	wheat	Orenburgskij
1193		++		1947	Millet, wheat PD C	weakly toxic	wheat	Orenburgskij
1208		++	+	1947	Millet, wheat PD C	weakly toxic	wheat	Orenburgskij
1225		++	+	1947	Millet, barley AP M C	non-toxic	millet	Orenburgskij
1229		+++	++	1947	Millet C-P C	non-toxic	soil	Orenburgskij
1369		++	+	1948	Millet, barley AP M C	non-toxic	millet	Orenburgskij
1464		++	+++	1948	Millet, barley AP M C	non-toxic	millet	Orenburgskij
1530		+++	+	1948	Millet, wheat PD M C	non-toxic	wheat	Orenburgskij
1555		+++		1948	Millet CP C	non-toxic	soil	Orenburgskij
1656		+++	+	1948	Millet, barley AP M C	non-toxic	millet	Orenburgskij
1670		+++		1948	Millet, wheat AP	non-toxic	wheat	Dombarovskij
1823		+++	++	1948	Millet, barley C	non-toxic	barley	Orenburgskij
1830		++	+	1948	Millet, barley C	non-toxic	barley	Orenburgskij
1869		+++	++	1948	Millet, barley C	non-toxic	barley	Orenburgskij
1883		++		1948	Millet, wheat PD C	weakly toxic	wheat	Orenburgskij
1919		++	+	1948	Millet, barley C	non-toxic	barley	Dombarovskij

* SYMBOLS:

AP — Acid potato agar
C — Czapek agar
M — Malt agar
CP — Carbohydrate-peptone agar
PD Potato-dextrose agar
v.p. of pl. Vegetative parts of plant
L — Leucocytorrhoea
O — Oedematous reaction
H — Haemmorrhage reaction

TABLE 1 (Continued)

Culture characteristics of Fusarium sporotrichioides *Sherb.*

No. of culture	Toxicity of cultures L	O	H	Year of isolation	Culture medium	Toxicity of original host	Original host	County of collection
1933		++	+	1948	Millet, barley C	non-toxic	barley	Orenburgskij
2127		+++	++	1948	Millet, barley AP M	non-toxic	barley	Dombarovskij
2193		++		1948	Millet, barley C	non-toxic	barley	Orenburgskij
2270		++	+	1948	Millet, barley C	non-toxic	barley	Orenburgskij
2273		++	+	1948	Millet, barley AP C	weakly toxic	barley	Orenburgskij
2276		+++	++	1948	Millet, barley C	non-toxic	barley	Orenburgskij
2335		++	+	1948	Millet, barley C	non-toxic	barley	Orenburgskij
2342		++	++	1948	Millet, wheat PD	non-toxic	wheat	Orenburgskij
2465		+++	+	1949	Millet, barley AP C	non-toxic	barley	Orenburgskij

In Table II the results of investigations of 66 cultures of *Fusarium poae* (PK.) Wr. are shown; 46 of them were characterized by high toxicity, 20 by slight toxicity.

TABLE II

Characteristics of Fusarium poae (*PK.*) *Wr. strains*

No. of culture	Toxicity of cultures L	O	H	Year of isolation	Culture medium	Toxicity of original host	Original host	County of collection
345		+	+	1944	Millet, barley AP M C	highly toxic	millet	N.-Sergievskij
401	+	+		1944	Millet, wheat PD C	weakly toxic	wheat	Orenburgskij
585	+			1945	Millet, barley AP M	weakly toxic	barley	Orenburgskij
619	+			1945	Millet, barley AP	weakly toxic	v.p. of pl. barley	Orenburgskij
655		+		1945	Millet, wheat PD C	non-toxic	v.p. of pl. wheat	Orenburgskij
688		+		1945	Millet, wheat PD	non-toxic	wheat	Orenburgskij
692	+			1945	Millet, husks AP PD	non-toxic	millet	Orenburgskij
954	+			1947	Millet, barley C	toxic	rye	Zianchurinskij
1059		+		1947	Millet, barley AP	non-toxic	v.p. of pl. barley	Orenburgskij
1164		+		1947	Millet, barley C	non-toxic	barley	Orenburgskij
1185		+		1947	Millet, barley C	non-toxic	barley	Orenburgskij
1221		+		1947	Millet, barley C-P C	non-toxic	soil	Orenburgskij
1226	+			1947	Millet, barley C	non-toxic	barley	Orenburgskij
1240	+			1947	Millet, barley C	weakly toxic	barley	Orenburgskij
1377		+		1948	Millet, barley C-P C	non-toxic	soil	Orenburgskij
1547	+			1948	Millet AP PD	non-toxic	millet	Ak.-Bulakskij
1557		+		1948	Millet, barley	non-toxic	barley	Orenburgskij
1686		+		1948	Millet C-P C	non-toxic	soil	Sakmarskij
2125		+		1948	Millet, barley C	non-toxic	barley	Orenburgskij
2126		+		1948	Millet, barley C	non-toxic	barley	Orenburgskij
60/9		+++	++	1944	Millet husks, barley AP C	highly toxic	millet	Sol-Iletskij
344		+++	+	1944	Millet, barley AP C	highly toxic	millet	N.-Sergievskij
346		++	++	1944	Millet, barley AP C	highly toxic	millet	N.-Sergievskij
348		++	++	1944	Millet, barley AP C	highly toxic	millet	N.-Sergievskij
350		++		1944	Millet, barley AP C	highly toxic	millet	N.-Sergievskij
395		+++	+	1944	Millet husks PD M	toxic	millet	Orenburgskij
396		+++	+++	1944	Millet husks PD C	toxic	millet	Orenburgskij
426	+++			1944	Millet, barley AP	toxic	barley	Orenburgskij
467	++			1944	Millet, barley PD	toxic	barley	Orenburgskij
792	+	+++	++	1946	Millet, barley AP	weakly toxic	barley	Orenburgskij
856		+++	++	1947	Millet, barley PD C	non-toxic	millet	Orenburgskij
914		+++		1947	Millet, wheat AD C	highly toxic	wheat	S.-Iletskij
923		+++		1947	Millet, barley C	toxic	rye	Zianchurinskij
928	++	+++		1947	Millet husks, barley AP C	weakly toxic	millet	S.-Iletskij

TABLE II (Continued)

Characteristics of Fusarium poae (*Pk.*) *Wr. strains*

No. of culture	Toxicity of cultures L	O	H	Year of isolation	Culture medium			Toxicity of original host	Original host	County of collection
958	+	+	+	1947	Millet, wheat	PD	C	toxic	wheat	Sakmarskij
975	+	+	+	1947	Millet husks	PD	M	weakly toxic	millet	Orenburgskij
985				1947	Millet husks	PD	M	non-toxic	v.p. of pl. millet	Orenburgskij
986		+		1947	Millet, wheat	PD	C	toxic	wheat	Orenburgskij
988		+		1947	Millet, barley		C	toxic	rye	Zianchurinskij
994			+	1947	Millet, wheat	PD	C	non-toxic	wheat	Orenburgskij
1190		+		1947	Millet, barley	AP		non-toxic	barley	Orenburgskij
1370			+	1948	Millet, wheat	PD		non-toxic	wheat	Orenburgskij
1372		+		1948	Millet, wheat	PD		non-toxic	wheat	Orenburgskij
1374		+	+	1948	Millet	C-P	C	non-toxic	soil	Orenburgskij
1539		+	+	1948	Millet, wheat	PD	C	non-toxic	wheat	Ak.-Bulakskij
1633				1948	Millet	C-P	C	non-toxic	soil	Orenburgskij
1825			+	1948	Millet, barley		C	non-toxic	barley	Orenburgskij
1858				1948	Millet, barley		C	non-toxic	barley	Orenburgskij
1903		+	+	1948	Millet, barley		C	non-toxic	barley	Orenburgskij
1912		+	+	1948	Millet, barley		C	non-toxic	barley	Orenburgskij
1916				1948	Millet, barley		C	non-toxic	barley	Dombarovskij
1941				1948	Millet, wheat	PD	C	weakly toxic	wheat	Orenburgskij
1960		+		1948	Millet, barley		C	non-toxic	barley	Orenburgskij
2001		+		1948	Millet, barley		C	non-toxic	barley	Orenburgskij
2106				1948	Millet, barley		C	non-toxic	barley	Orenburgskij
2121				1948	Millet, barley		C	non-toxic	barley	Orenburgskij
2128		+	+	1948	Millet, wheat	PD	C	weakly toxic	wheat	Orenburgskij
2158				1948	Millet, barley	PD	C	non-toxic	barley	Orenburgskij
2189				1948	Millet, wheat	PD	C	weakly toxic	wheat	Orenburgskij
2272		+		1948	Millet, wheat	PD	C	non-toxic	wheat	Orenburgskij
2274				1948	Millet, barley	PD	C	non-toxic	barley	Orenburgskij
2275		+		1948	Millet, barley	PD	C	non-toxic	barley	Orenburgskij
2340				1948	Millet, barley	PD	C	non-toxic	barley	Orenburgskij
2380				1948	Millet, wheat	PD	C	non-toxic	wheat	Orenburgskij
2520				1949	Millet, wheat	AP	M C	non-toxic	sunflower	Kurmanaevskij
2627				1949	Millet, barley	PD	C	weakly toxic	barley	Dombarowskij

As seen from Table III, 52 cultures belonged to various species of *Fusarium*; 22 of them were highly toxic, the remaining 30 slightly so.

For an evaluation of toxicity of the various Fusaria, the author studied the nature of skin reactions produced by these fungi, noting the degree of leucocytorrhoea, oedema and haemorrhage, using the same method that had been applied by him in testing the toxicity of other fungi (Joffe and Mironow 1947).

The mildly toxic cultures shown in Tables I, II, III generally produced no haemorrhage on the rabbits' skin, but led to the development of an inflammatory reaction which disappeared after 72 hours (reddening and formation of slight leucocytorrhoea with or without slight oedema was recorded). The intensity of these reactions was marked +.

TABLE III

Characteristics of strains of Fusarium *species*

No. of culture	Name of fungus	Toxicity of cultures L	O	H	Year of isolation	Culture medium	Toxicity of original host	Original host	County of collection
368	*F. kühnii* (Fuck.) Sacc.	+			1944	Millet AP C	weakly toxic	millet	N.-Sergievskij
944	*F. nivale* (Fr.) Ces.	+	+		1947	Millet AP,PD	weakly toxic	millet	S. Iletskij
996	*F. nivale* (Fr.) Ces.		+		1947	Millet AP,PD	weakly toxic	millet	S. Iletskij
2457	*F. tricinctum* (Cda.) Sacc.		+		1948	Millet AD,M	non-toxic	barley	Orenburgskij
1174	*F. tricinctum* (Cda.) Sacc.		+++	++	1947	Millet AP,M	non-toxic	millet	Orenburgskij
1227	*F. tricinctum* (Cda.) Sacc.		++	+	1947	Millet AP,M	non-toxic	millet	Orenburgskij
809	*F. arthrosporioides* Sherb.		+		1946	Millet	non-toxic	barley	Orenburgskij
1163	*F. avenaceum* (Fr.) Sacc.		+	+	1947	Millet, barley AP C	non-toxic	wheat	Orenburgskij
137	*F. graminum* Cda.	+			1944	Millet, barley AP	weakly toxic	wheat	Orenburgskij
1448	*F. graminum* Cda.		+	+	1948	Millet, barley AP	non-toxic	v.p. of pl. millet	Orenburgskij
1018	*F. avenaceum* (Fr.) Sacc.		+++	++	1947	Millet PD C	non-toxic	barley	Orenburgskij
1403	*F. avenaceum* (Fr.) Sacc.		++		1948	Millet PD C	weakly toxic	barley	S. Iletskij
1061	*F. graminum* Cda.	+	++		1947	Millet, barley AP	non-toxic	barley	Orenburgskij
1559	*F. diversisporum* Sherb.	+	+		1948		non-toxic	wheat	N.-Orskij
1378	*F. semitectum* Bert. et Rav.		+		1948	Millet, wheat M	non-toxic	millet	Orenburgskij
1265	*F. semitectum* Bert. et Rav.		++	+	1947	Millet, wheat M	non-toxic	barley	Orenburgskij
2466	*F. semitectum* Bert. et Rav.	+	+	++	1949	Millet, wheat M	non-toxic	millet	Orenburgskij
1040	*F. equiseti* (Cda) Sacc.	+	+		1947	Millet, barley AP	non-toxic	millet	S. Iletskij
1106	*F. scirpi* Lamb. et Fautr.		+		1947	Millet, barley PD,M	non-toxic	soil	Orenburgskij
1860	*F. scirpi* Lamb. et Fautr.	+	+		1948	Millet, wheat PD,M	non-toxic	soil	Orenburgskij
1890	*F. scirpi* Lamb. et Fautr.		+		1948	Millet, wheat PD,M	non-toxic	barley	Orenburgskij
687	*F. equiseti* (Cda.) Sacc.		++		1945	Millet, barley AP	non-toxic	wheat	Orenburgskij
1900	*F. equiseti* (Cda.) Sacc.		++	+	1948	Millet, barley AP	non-toxic	wheat	Orenburgskij
2385	*F. equiseti* (Cda.) Sacc.	+	++	++	1948	Millet, barley AP	non-toxic	barley	Orenburgskij
2387	*F. equiseti* (Cda.) Sacc.		++	+	1948	Millet, barley AP	non-toxic	barley	Orenburgskij
2315	*F. scirpi* Lamb. et Fautr. v. *acuminatum* (Ell. et Ev.) Wr.		++	+	1948	Millet, barley PD,M	non-toxic	barley	Orenburgskij
1140	*F. scirpi* Lamb. et Fautr.	++	+		1947	Millet, barley PD,M	non-toxic	millet	Orenburgskij
359	*F. scirpi* Lamb. et Fautr.	+	+	++	1944	Millet, barley PD,M	non-toxic	millet	Orenburgskij
765	*F. graminearum* Schwabe			+	1946	Millet, barley AP	toxic	wheat	Orenburgskij

TABLE III (Continued)

Characteristics of strains of Fusarium *species*

No. of culture	Name of fungus	Toxicity of cultures L	O	H	Year of isolation	medium Culture	Toxicity of original host	Original host	County of collection
843	*F. culmorum* (W. G. Sm.) Sacc.	+	+		1947	Millet, wheat PD	highly toxic	wheat	S. Iletskij
2328	*F. sambucinum* Fuck.	+			1948	Millet AP	non-toxic	wheat	Orenburgskij
1213	*F. culmorum* (W. G. Sm.) Sacc.	++	++		1947	Millet, wheat PD	weakly toxic	wheat	Orenburgskij
1540	*F. culmorum* (W. G. Sm.) Sacc.	+	++		1948	Millet, wheat PD	non-toxic	millet	Ak.-Bulakskij
1904	*F. sambucinum* Fuck.		++	+++	1948	Millet AP C	non-toxic	barley	Orenburgskij
1767	*F. lateritium* Nees		+		1948	Millet, barley C–P,PD	non-toxic	soil	Orenburgskij
2330	*F. lateritium* Nees		+		1948	Millet, barley C–P,PD	non-toxic	barley	Orenburgskij
2638	*F. lateritium* Nees	+	+		1949	Millet, barley C–P,PD	non-toxic	wheat	Dombarovskij
1421	*F. lateritium* Nees		++		1948	Millet husks AP	non-toxic	v. p. of pl. millet	Orenburgskij
2381	*F. lateritium* Nees		+	++	1948	Millet husks AP	non-toxic	wheat	Orenburgskij
989	*F. moniliforme* Sheld.	+	+		1947	Millet C–P,PD, C	weakly toxic	wheat	Sakmarskij
995	*F. moniliforme* Sheld.	+	+		1947	Millet C–P,PD, C	weakly toxic	soil	Orenburgskij
1863	*F. moniliforme* Sheld.	+	+		1948	Millet C–P,PD, C	non-toxic	barley	Orenburgskij
2269	*F. moniliforme* Sheld.		+		1948	Millet AP C	non-toxic	barley	Orenburgskij
1857	*F. moniliforme* Sheld.		++	+	1948	Millet AP C	non-toxic	barley	Orenburgskij
847	*F. orthoceras* App. et Wr.	+			1947	Millet AP C	non-toxic	v. p. of pl. wheat	Orenburgskij
1465	*F. oxysporum* Schlecht.		+		1948	Millet PD C	non-toxic	soil	Orenburgskij
1637	*F. oxysporum* Schlecht.		+	+	1948	Millet PD C	highly toxic	wheat	Orenburgskij
2317	*F. redolens* Wr.		++		1948	Millet PD C	non-toxic	wheat	Orenburgskij
2341	*F. oxysporum* Schlecht.		++	+	1948	Millet PD C	non-toxic	wheat	Orenburgskij
965	*F. solani* (Mart.) App. et Wr.	+			1947	Millet C	toxic	wheat	Sakmarskij
990	*F. solani* (Mart.) App. et Wr.	+	+		1947	Millet C	highly toxic	wheat	Sakmarskij
1664	*F. solani* (Mart.) App. et Wr.		+		1948	Millet C	highly toxic	millet	Orenburgskij

The toxic and highly toxic Fusaria produced an oedematous haemorrhagic reaction (Figure 1), or leucocytorrhic or leucocytorrhic oedematous reaction (necrotic non-healing ulcers, which lasted 20 days or more, were formed). The intensity of these reactions was recorded as ++ or +++.

Skin reactions caused by the action of *Fusarium*-extracts were thus distinguished both by their external appearance and by histological changes.

The toxic *Fusarium* extracts often had a general toxic effect on the rabbits, manifested by a loss of appetite and weight, sleepiness and changes in blood composition; in several cases the animals died after the application of the toxin.

A relationship was found between the nature of the toxic *Fusarium* cultures and the toxicity of the samples from which they had been isolated. Some of the *Fusarium*

Figure 1

Skin reactions of rabbit on the spots where *Fusarium sporotrichioides* (left) and *Fusarium poae* (middle) were applied. (Spot on the right-control).
Photograph taken 48 hours after application.

cultures caused reactions on the skin of rabbits which were analogous to those produced by the action of toxic cereals which had passed the winter under snow cover.

When toxic fungi were discovered on these cereals, it was decided to study their general toxic effect on animals, in order to find out their etiological role in the provocation of septic angina. For this purpose various animals were tested.

Frogs were tested in order to establish the toxicity of *Fusarium poae*. About 50 frogs were fed per os with dry fungi in various doses. Following repeated feeding with the fungi the animals died after 4, 6 and 11 days respectively, depending on the dose, or, more rarely, after 14 days. The effect of the toxin was cumulative. Post mortem dissection showed extreme hyperaemia, haemorrhage and oedema of the digestive tract.

The effect of extracts from millet grain experimentally infected with *Fusarium poae* and *F. sporotrichioides* was studied on certain Protista.

The method of experiments was as follows: To 0.1 ml of extract 0.1 ml of 96% ethyl alcohol and 5 ml distilled water were added, as in previous study of the effect of different fungal toxins on *Paramaecium* (Drabkin and Joffe 1950). On it it was

established by a series of experiments that alcohol in the concentration used has no toxic effect on *Paramaecium caudatum* during the first 24 hours. From the stock solution various extracts of lower concentration were prepared. The experiments were made in the concentration 1:1000, in three replications. It was found that alcoholic extracts of infected millet grain had a toxic effect on *Paramaecium caudatum*.

In order to find out whether *Fusarium* extracts have only a protistocidic effect on *Paramaecium*, or whether their protistocidic spectrum is a wider one, ether extracts of whole colonies of *F. poae* were tested on 4 different Protista: *P. caudatum*, *Stylonychia mytiles*, *Opalina ranarum* and *Nyctotheras cordiformis*. The results observed prove that the *F. poae* extracts have a similar effect on all Protista tested. Other moulds studied by the author did not have a protistocidic effect (Drabkin and Joffe 1952). Thus it was established that cultures of *F. poae* and *F. sporotrichioides* have a lethal effect on living cells.

The toxic properties of *F. poae* and *F. sporotrichioides* were also tested on white mice. The mice died 2–7 days after they had been fed per os either on cultures of the two *Fusarium* species, grown on agar (0.02 g), or on cultures prepared from infected millet (0.5–1.5 g), on *Fusaria* extract (0.005–0.008 g), or on dry fungi (0.01 g) and their liquid filtrates (0.2–0.3 ml). Subcutaneous infections of fungus filtrates prepared during their abundant sporulation produced a lethal effect after 13–18 hours, or, more rarely after 24 hours.

Guinea pigs and rabbits were given liquid filtrates and powdered dry mycelium of the toxic *F. poae*, *F. sporotrichioides*, *F. lateritium*, *F. tricinctum*, *F. sambucinum*, *F. semitectum* and *F. equiseti*. The guinea pigs were given per os 1.0–2.0 ml of the culture liquid each, or 0.05–0.07 g of dry fungus; the rabbits received 3–5 ml filtrate each, and 0.1–0.15 g mycelium each. On the 5th–21st day after the feeding, all guinea pigs died; those which received the toxic fungi in liquid form, suffered most from the disease. The rabbits died on the 8th–24th day after feeding on toxic cultures. The autopsies of almost all animals showed haemorrhage in organs and tissues, dilated blood-vessels and haemorrhage in the walls of the intestines.

For the study of the general toxic effect on cats tests were made with *F. poae* and *F. sporotrichioides* in the form of agar cultures, millet cultures, dry mass, and culture liquid. All cultures of *Fusarium* had a strong reaction of anecrotic type. The daily dose of agar and millet cultures was 0.05–0.12 g and that of the liquid substrate 0.5–1.0 ml. In all the forms administered to cats, both *Fusarium* species were lethal after periods of time dependent on the daily fungus dose, and on individual properties of the respective organism. The death of the cats followed a breakdown in blood production. In cats under experiment a decline in the percentage of haemoglobin, in the number of erythrocytes, leucocytes, neutrophils as well as a rise in the amount of lymphocytes was observed. In the majority of cases the cats died on the 6th–12th day. Autopsy revealed high hyperaemia of internal organs, especially of the digestive tract and kidneys and extreme changes in the adrenal glands. Histological examin-

ations of organs of cats which had died after infection of *F. poae* revealed changes in the blood producing tissue, which were similar to those produced by septic angina in humans. It should be added that cats were found to be the best model on which the whole clinical picture of septic angina could be reproduced.

The effect of different quantities of agar cultures of *F. poae* on the motor activity of dogs has also been studied by the author (Hrootsky and Joffe 1953). Feeding of *Fusarium poae* cultures per os and through a stomach fistula was made under various conditions, namely normal contractions, quiet static intervals and periodic motor activity of the stomach. The fungus culture administered to the dog had been mixed with 200 g of meat, and the results were registered by a kimograph. 38 experiments were made, each lasting 3–6 hours. It was found that introduction of large fungus doses (1 g and more) produced poisoning of the animal and cessation of the stomach's motor activity.

Very thorough experiments were made with feeding of *Fusarium poae* cultures to two horses (Antonov, Belkin, Joffe, *et al.* 1951). Two series of agar cultures grown under different conditions were used. The first series grown at room temperature without being subjected to freezing and subsequent thawing. The second series, grown at low temperatures, was found to be more toxic than the first. 40 g of fungus culture of the second series produced an acute toxicosis. The horse died 36 hours after the administration of the culture. The symptoms found by clinical as well as pathologic anatomic and histologic examinations were those of haemorrhagic diathesis.

Minimal doses of *F. poae* (1st series) produced phenomena of toxicosis in the horse with a typical clinical picture and deviations.

Data from literature concerning the effect of *F. poae* on the organism of animals are extremely rare. Only Pidoplichka and Bilay (1946) report that guinea pigs and rabbits, which received *F. poae*, died. Our observations proved that the tested fungus is apparently more highly toxic than *F. sporotrichioides*. Thus according to Sarkisov *et al.* (1948) the feeding of a horse with 16.4 kg cereals infected by *F. sporotrichioides* caused the development of stomatitis and gingivitis only, while our experiment showed that 40 g of a culture of *F. poae* resulted in the death of a horse within 36 hours.

Using our material, Olifson studied the chemical composition of millet artificially infected with toxic, slightly toxic and non-toxic cultures of *Fusarium poae* and *F. sporotrichioides* (Sect. Sporotrichiella) (Olifson 1956). The purpose of this study was the determination of the chemical structure of metabolic products of *F. poae* and *F. sporotrichioides*. The chemical composition of millet grain changed drastically after its infection with the named fungi. The toxic strains caused more profound changes in the grain than the weakly toxic or non-toxic ones. This problem has been studied previously by the authors (Olifson, Drabkin and Yoffe 1950, Olifson and Yoffe 1954). From the grain infected by the two *Fusarium* species toxic sub-

stances designated as sporofusariogenin and poaefusariogenin, were isolated and their chemical structure was tentatively established. Growing of *Fusarium* cultures at constant temperature promotes the formation of triglycerides, while their growth at sharply fluctuating temperatures (alternate freezing and thawing) raises toxicity considerably, and brings about the formation of free acids and of neutral substances, mainly of toxic sterols. In experiments on mice and cats these substances caused a stable leucopenia.

Available data from literature show that certain *Fusarium* cultures are antibiotically active in respect to *Mycobacterium tuberculosis*, and therefore these fungi drew our attention. The first antibiotic obtained from *F. javanicum* is the pigment javanicin, which is highly active against *Staphylococcus* and the tubercle bacillus (Arnstein, Cook and Lacey 1946). Cook, Cox, Farmer and Lacey (1947) obtained several other antibiotics from *Fusarium* species: lateritin I, avenacein, fructigenin and sambucenin, all active against *Mycobacterium phlei*. Later Texer (1948) isolated two antibiotics from *F. hyperoxysporum* Woll., and Platter and others (1948) found a substance very active against *M. tuberculosis* from *F. orthoceras* var. *enniatum*.

In connection with these data, we started a study on the effect of some *Fusarium* species on the tubercle bacillus. *Fusarium* and penicillin cultures had also been previously tested in this respect (Joffe 1955). The results of the present study of different species of *Fusarium* are presented in Table IV.

TABLE IV

Number and percentage prevalence of Fusarium *cultures effective against* avium, bovinus *and* humanus *types of* M. tuberculosis

Culture medium	*avium*	% active cultures	*bovinus*	% active cultures	*humanus*	% active cultures
Synthetic Czapek	4	6.3	3	4.7	5	7.9
Carbohydrate peptone	4	6.3	—		—	

As shown on Table IV, *Fusarium* cultures grown on the Czapek medium were the most active ones in respect to *M. tuberculosis*.

Repeated subcultures were transferred onto the Petraniani medium following the action of antibiotics on *M. tuberculosis* typ. *avium*, *bovinus* and *humanus*. Sometimes the filtrates of *Fusarium* dissolved the tubercle bacilli entirely leaving only a drop of oil on the bottom of the test tube; in other cases these filtrates prevented growth of the bacilli both on solid and on liquid medium. The effect of antibiotics on the morphology of *M. tuberculosis* t. *avium*, grown on a 5% glycerin calf boullion was also studied. While in the control cultures the bacilli were slender and long, and usually contained 1–2 granules, the bacilli to which filtrates of fungi were added,

were in the majority of cases thick and polymorphic, sometimes diphteria-like or flaskshaped, with numerous granules. After investigating the antibiotic activity of *Fusarium* cultures, it was decided to establish their toxicity. For this end, alcoholic extracts of the fungus thallus were applied to the shaven skin of rabbits twice with an interval of 24 hours. The rabbits used were sensitive, owing to their unpigmented skin, and their weight was 2.5 kg. The reactions were registered after 48 hours, but the rabbits remained under observation for a period of 6–8 days. In addition, the control of toxicity was tested on white mice by subcutaneous injections of the antibiotic under investigation (in quantities of 0.2, 0.4, 0.6 and 0.8 ml). The results of toxicity tests on rabbits were completely identical with those obtained on mice. On Table V the data relating to antibiotic properties, origin and toxicity of *Fusarium* cultures are set out. As seen from this table, culture No. 665 (*F. avenaceum*) prevented growth in *M. tuberculosis avium, bovinus* and *humanus*. Cultures No. 1546, 1886, 1754 (*F. orthoceras, F. sambucinum, F. javanicum*) acted effectively against two types of *M. tuberculosis*. The activity of some of the *Fusarium* cultures (No. 343, 1485) varied

TABLE V

Characteristics of strains of Fusarium *species*

No. of Culture	Name of fungus	Original host	Toxicity	Medium	*M. tuberculosis*		
					avium	*bovinus*	*humanus*
343	*F. sporotrichioides* Sherb.	millet	toxic	I	+	++	++
1485	*F. martii* App. et Wr.	wheat	non-toxic	I	+	++	++
921	*F. sporotrichioides* Sherb.	rye	toxic	I	+	+	+
1546	*F. orthoceras* App. et Wr.	millet	non-toxic	I	+	0	0
1638	*F. moniliforme* Sheld.	millet	non-toxic	I	+	+	0
1878	*F. lateritium* Nees	wheat	non-toxic	I	+	+	+
1376	*F. oxysporum* Schlecht.	soil	non-toxic	I	+	+	+++
1886	*F. sambucinum* Frick.	barley	non-toxic	I	0	+	0
665	*F. avenaceum* (Fr.) Sacc.	barley	reddening	I	0	0	0
1754	*F. javanicum* Koorders	wheat	non-toxic	I	+	0	0
1865	*F. solani* (Mart.) App. et Wr.	barley	weakly toxic	I	0	++	++
1748	*F. lateritium* Nees	barley	non-toxic	I	++	+	+
1918	*F. semitectum* Berk. et Rov.	barley	non-toxic	I	0	+	+
1782	*F. moniliforme* Sheld.	soil	non-toxic	I	++	++	+
1728	*F. scirpi* Lamb. et Fautr.	millet	non-toxic	I	++	+	++
2153	*F. bulbigenum* Cke. et Mass.	millet	non-toxic	I	++	++	+
1016	*F. orthoceras* App. et Wr.	millet	non-toxic	I	++	++	+
343	*F. sporotrichioides* Sherb.	millet	toxic	III	0	++	++
1485	*F. martii* App. et Wr.	wheat	non-toxic	III	0	++	++
1577	*F. sambucinum* Fuck.	millet	non-toxic	III	0	++	++
1579	*F. oxysporum* Schlecht.	wheat	non-toxic	III	+	+	++
1918	*F. avenaceum* (Fr.) Sacc.	barley	weakly toxic	III	0	++	++
2388	*F. lateritium* Nees	barley	weakly toxic	III	++	+	+
562	*F. poae* (PK.) Wr.	millet	doubtfully toxic	III	++	++	+
1040	*F. equiseti* (Cda.) Sacc.	millet	weakly toxic	III	+	++	++
	Control				+++	+++	+++
	Control				+++	++	+++

SYMBOLS:

I — Synthetic Czapek medium
III — Carbohydrate–peptone medium
0 — No growth of *M. tuberculosis*

\+ — Weak growth
++ — Satisfactory growth
+++ — Abundant growth

with the culture medium. The table also shows that two *Fusarium* cultures were found toxic, six cultures had a weak or doubtful toxicity, while the rest were non-toxic.

A study of the antibiotic effect of several *Fusarium* cultures on dysentery and the typhus–paratyphus groups was also undertaken; 83 cultures were isolated from *Triticum*, *Panicum*, *Hordeum*, *Secale*, *Helianthus*, *Quercus*, from air and soil and other substrates. (The method for these tests had also been used previously; Joffe and Eshmantatite 1955). The following bacteria were tested: *B. typhosus*, *B. paratyphosus*, *B. dysenteriae* Flexner and *B. dysenteriae* Shiga.

The results are presented in Table VI.

TABLE VI

Antibiotic action of Fusarium *filtrates on several intestinal bacilli*

Name of tested bacillus	Medium I	% active cultures	Medium III	% active cultures
B. typhosus	5	5.9	4	4.8
B. paratyphosus B	3	3.7	1	1.2
B. dysenteriae Flexner	5	5.9	4	4.8
B. dysenteriae Shiga	—		4	4.8

See footnote of Table V for symbols.

From Table VI it is seen that the effect of the tested *Fusaria* grown on media I and III on *B. typhosus*, *B. paratyphosus* B, *B. dysenteriae* Flexner was not significantly different. However, on Czapek's medium the *Fusarium* cultures were completely inactive with respect to *B. dysenteriae* Shiga, whereas their positive effect on carbohydrate–peptone medium was noted in 4 cases. Of the 83 cultures tested, the most active with respect to the bacilli were *Fusarium lateritium*, *F. sporotrichioides*, *F. moniliforme*, *F. poae*, *F. solani*, *F. equiseti*, *F. sambucinum*, *F. semitectum*, *F. avenaceum*.

One-hundred-and-five cultures of *Fusarium* were also tested as to their effect on *Staphylococcus aureus*. Those cultures which were grown on carbohydrate–peptone medium (III) had only an insignificant antibiotic effect on *Staphylococcus aureus*, 2.8%, or 3 cultures, and on Czapek's medium (I) 6.7%, or 7 cultures.

Those active against *Staphylococcus aureus* were *Fusarium sambucinum*, *F. poae*, *F. equiseti*, *F. tricinctum*, *F. javanicum*.

One should remark that the antibiotic action of fungi on microbes of the intestine group and of *Staphylococcus aureus* was much more pronounced when serial dilutions were used instead of a solid medium in Petri dishes. The active *Fusarium* cultures exserted a bacteriostatic effect on the test-bacilli.

The dependence of the antibiotic properties of the fungus on the length of its growing period and on variations in *p*H values in the culture medium in the course

of its development were also studied. The highest antibiotic activity of *Fusarium* was mostly observed on the 11th–12th day of growth on Czapek's medium (I), and on the 14th–15th day on the carbohydrate–peptone (III) medium. Therefore, filtrates were usually tested after 11–15 days of growth. The *p*H prevailing on medium I on the 11th–12th day was 7.0–7.5%; on medium III it dropped to 6.1–7.0 on the 15th day.

CONCLUSIONS

1. Toxic fungi belonging to several species were isolated from wintered toxic and non-toxic cereals, soil and various other substrates. The majority of the toxic cultures belonged to *Fusarium poae* and *F. sporotrichioides* (Sect. Sporotrichiella), while a smaller number of cultures consisted of various other fungi.

2. Out of the 501 isolated *Fusarium* cultures the total number of toxic and highly toxic strains was 112 or 22.35% and that of slightly toxic strains 67 or 13.37%.

3. The toxins of *Fusarium* cultures have both a localized and a general toxic effect. The localized effect is first apparent in an inflammatory reaction and is accompanied by a subsequent skin necrosis on the spot of the toxin application. The general effect is apparent in defective blood production, parenchymatic organs, acute degeneration processes in the kidneys, adrenals, etc., as well as in extreme hyperaemia of internal organs, especially of the digestive tract.

4. The toxicity of *Fusarium* fungi was evaluated by testing the character of the reactions produced by their application to the bare skin of rabbits. The fungi produce, as a rule, an oedematous haemorrhagic reaction, and were often found to cause non-healing necrotic ulcers.

5. By feeding toxic cultures of *F. poae*, *F. sporotrichioides* and of other fungi to rabbits, cats, white mice, horses, etc., heavy poisoning with lethal results was caused.

6. In many cases *Fusarium* cultures displaying antibiotic properties were isolated from various cereals.

7. Some of these cultures showed antibiotic activity on the tubercle bacillus, on pathogenic bacteria of the coli group and on *Staphylococcus aureus*.

8. Comparing the results obtained during the study of antibiotic effects of Fusaria grown on a carbohydrate–peptone medium and on Czapek's medium, it may be concluded that the composition of the culture medium influences the process of accumulation of antibiotic substances.

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יוצא לאור ע"י

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